W. B. No. 769.

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1914: February, March, April, October, December.
1915: February, March, April, May, June, July, August, September.
1916: January, February, June, August, September.
1917: May.
1918: February, September.
1919: Any issue, especially August, November, December.
1920: Any issue, especially January.
1921: August, September, October, November.
SUPPLEMENTS, Nos. 2 and 3.

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ALFRED J. HENRY, Editor.

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THE NEW PRECIPITATION SECTION OF THE ATLAS OF AMERICAN AGRICULTURE.

By Robert De C. Ward.

[Harvard University, March 17, 1922.]

Introduction.—The preparation of a section on Climate for the new *Atlas of American Agriculture* marks a very important advance in the accurate charting and discussion of many of the essential features of the climates of the United States. As yet. but one part of this section has been issued in its final form, viz, that on Frost.[1] The *Precipitation* section has been printed but not yet bound or distributed. Sets of the loose sheets have, however, been sent to a limited number of teachers and others to whom the material is of immediate practical use. The *Humidity* folio is still to be lithographed and printed. The complete *Precipitation* and *Humidity* section will therefore probably not be ready for distribution in its final form, for several months. The *Temperature* section is, unfortunately, still further from completion.[2] Advance publication has been made of the new mean annual, monthly, and seasonal rainfall maps,[3] all of which have previously been reviewed by the present writer.[4]

General description of the precipitation section.—The precipitation section comprises 85 figures, of which 16 are diagrams and 69 are maps. Of the maps, 16 show the monthly and seasonal, and one shows the mean annual precipitation. With these, the present discussion does not deal. The text covers 5½ pages. Taken altogether, this new series of charts and diagrams constitutes one of the most notable contributions to climatology of recent years. Not only is the series remarkably complete, more so than any previous set of similar charts, but, what is even more essential, records for a uniform basic period of 20 years (1895–1914) were employed in the construction of all the principal maps and graphs. About 1,600 stations have records for the full 20-year period. Additional shorter records from about 2,000 other stations were also used. These all come within the 1895–1914 period—vary in length from 10 to 19 years, and were reduced to the basic 20-year period by well-known methods. The result is not only a more complete but a far more accurate compilation of precipitation data for the United States than has hitherto been possible. Especially is this true of the more recently settled portions of the country and of the higher altitudes of the West. In the case of these last-named districts the mountain snowfall records were found very useful as a guide in drawing the isohyetal lines. In addition, the amounts of precipitation at the higher elevations (where there is a great lack of actual rainfall records) were inferred from the known increase of precipitation with elevation; from the character of the vegetation, and from the stream flow, wherever reliable data on these conditions were available.

Departures from the average rainfall.—The principal and most immediate object in view in the preparation of this new precipitation folio was to benefit agriculture. From the agricultural standpoint, the mean annual and mean monthly rainfalls are by no means altogether satisfactory. In the case of the former, the period is so long that deficiencies in certain parts of the year which are of critical importance to crops may be wholly concealed by excess precipitation at other times of the year. Further, the annual amounts are often of secondary importance to the seasonal distribution. Nor are the monthly charts always of great value, for they show only the average conditions during the arbitrary unit of a calendar month, which unit often has but little importance in the growth of crops. For these and other reasons, increasing emphasis has lately been laid upon seasonal precipitation charts, which, combining as they do the conditions of three months, give better information regarding the amounts of rainfall available for crops during their critical periods of growth. This new monograph very rightly emphasizes the importance of seasonal precipitation by including five full double-page charts, one each for the four seasons and one for the warm season, April–September, inclusive. An especially noteworthy feature of the new folio is the marked emphasis which it lays upon the departures which may be expected from the average rainfall. More and more, as climatological investigation progresses, is it realized that far too much attention has in the past been paid to *means*. It matters little to the farmer to know that the *mean* or *average* rainfall over his section is sufficient for the growth of a large crop if in some seasons his fields are parched during an "unusually" dry time and in others his crops suffer from "excessive" rains. He needs to know what departures from the average he may expect in the run of the years. He is then in a position to decide for himself what crops he may plant with the greatest probability of success. It is good, therefore, to see at the bottom of each seasonal and monthly chart a graph which shows, for a group of selected stations, the seasonal or monthly precipitation for each of the 20

[1] See review by R. De C. Ward: "Frost in the United States," *Geogr. Rev.*, vol 7, May, 1919, pp. 339–344.

[2] R. De C. Ward: "Some Characteristics of United States Temperatures," Mo. Weather Rev., November 2, 1921, **49**: 595–606; Charts XX.

[3] R. De C. Ward: "Mean Annual Rainfall of the United States, with Notes on the New Chart of Average Annual Precipitation from the 'Atlas of American Agriculture' (Advance Sheet)," *ibid*, July, 1917, pp. **45**: 338–345; chart.

J. B. Kincer: "The Seasonal Distribution of Precipitation and its Frequency and Intensity in the United States," *ibid*, September, 1919, **47**: 624–631; Charts XVI.

[4] R. De C. Ward: "New Monthly and Seasonal Rainfall Maps of the United States," *Geogr. Rev.*, vol. 9, September, 1920, pp. 173–181, with the four seasonal charts redrawn and somewhat simplified.

years of the basis period on which the chart is based. These diagrams show the variations which are likely to occur from year to year. They indicate the "relative dependability" of the means. Similarly, a full-page set of diagrams (fig. 5) shows the annual precipitation at 56 selected stations, arranged by geographic districts, for each of the years 1895 to 1914, inclusive. The facts here presented show the variations which may be expected from year to year in different sections and the general geographic distribution of these variations. It is seen that the larger variations occur on the Pacific slope, over the Great Plains, and in the Gulf States.

Many other new and economically important details regarding the variability of rainfall are also shown. From a chart of the relative frequency during the period 1895–1914 of an annual precipitation less than 85 per cent of the average (fig. 7), it appears that in the vicinity of Yuma, Ariz., less than 85 per cent of the annual precipitation fell in half the years, while more than 85 per cent of the annual mean fell in over 90 per cent of the years in parts of the Lake region, of the Atlantic Coast States, and of Tennessee. Another chart, of the relative frequency of warm-season precipitation (April–September) less than 75 per cent of the average, brings out facts of great agricultural importance (fig. 11). The warm-season rainfall was less than three-fourths of the average in 8–11 years (of the 20-year period) in southern California and parts of the adjoining States, but, fortunately for the great agricultural interests of the region east of the Rocky Mountains, a warm-season precipitation of less than 75 per cent of the average occurred in only two to four seasons during the 20 years. For each of the eight months July to October the relative frequency of monthly precipitation less than half the average is charted (figs. 58–65). The practical value of these charts may be realized by an examination of the facts which appear on any one of them. Take, e. g., that for July, a critical month for many of our great staple crops. It appears that in the central and eastern portions of the Cotton Belt there are a number of localities where only one July with a deficiency of more than one-half of the average rainfall occurred in 20 years. At some points in no year was the July rainfall less than half the average The districts east of the Mississippi River, as a rule had few deficiencies of 50 per cent. On the other hand, the percentages of frequency of a July precipitation less than half the average are large on the Pacific slope, espcially in California. As a whole, the variations above and below the normal are more frequent west of the Rocky Mountains, especially in summer.

Rainfall types.—The question "*When* does the rain fall?" being, for the agriculturist, often of more importance than the question "How much rain falls?" it is natural and logical that considerable attention should be paid to rainfall types and to illustrations of rainfall distribution through the year. The discussion of this matter occupies somewhat over a page of the text (pp. 16 and 37). In place of the 11 types of seasonal distribution recognized by Prof. A. J. Henry, 6 types are here adopted as sufficient "with respect to their agricultural significance and areas covered."[6] These are named Pacific, Sub-Pacific, Arizona, Plains, Eastern, and Florida and are illustrated by a series of percentage graphs for selected stations, the separate graphs being placed, in their proper locations on a general map of the United States (fig. 13). The question whether these types are permanent or might in some respects be altered if a different series of years were adopted was investigated.

It appeared that the Pacific type is less constant in relative monthly distribution than are the Eastern and the Plains types, but the distinguishing characteristics are maintained, even if different periods of years are used. Caution may, however, well be used in emphasizing the characteristics of the less distinctive types as indicated by the relatively short period of 20 years. The Eastern type (including the originally forested eastern United States except the Florida peninsula) has comparatively uniform precipitation through the year. In general, autumn has the least seasonal rainfall. This is particularly true of the Cotton Belt, and it there constitutes a very favorable condition for cotton picking. The Plains type (including the prairie and Plains regions and extending westward to the crest of the Rocky Mountains) has a marked late spring and summer maximum, with a dry winter. In the Arizona type (western Texas, New Mexico, and Arizona) July and August bring the heaviest rainfall. The Sub-Pacific type (covering most of the country between the Rocky Mountains and the Sierra Nevada and Cascade Ranges, and north of the Arizona type) has most of its precipitation during the winter and spring months. The Pacific type (between the Sierra Nevada-Cascades and the Pacific) has wet winters and dry summers. A heavy late summer or early autumn rainfall characterizes the Florida peninsula.

Four small charts (figs. 21, 31, 41, 51) show the percentages of the annual precipitation which come in each season. In winter the area having the highest percentages of the annual is on the Pacific coast (40–60 per cent); in spring the northern Rocky Mountain and Eastern Foothill regions have the highest percentages (30–35 per cent), but high percentages (over 30 per cent) are found westward into Idaho and Nevada and eastward well onto the Plains. In summer the area of highest percentages is still farther east over the Plains proper (40–50 per cent). There is thus seen to be a seasonal migration of the area of (relatively) heavy precipitation from the Pacific coast eastward to the Great Plains between winter and summer corresponding to the seasons of maximum and of minimum marine and continental controls. The Plains have roughly the following seasonal distribution: Winter, less than 10 per cent; spring, 25–30 per cent; summer, 40–50 per cent; autumn, 15–20 per cent. The percentage of the annual precipitation occurring between April 1 and September 30 is highest (over 70 per cent) over most of the great agricultural region of the eastern United States, embracing the eastern Plains and the Prairie States, a fact which brings out in startling prominence the agricultural importance of the "Plains" type of rainfall, with its late spring and early summer maximum (fig. 3). A small diagram (fig. 4) shows the period of the year within which 50 per cent of the annual precipitation occurs. A double-page chart (fig. 15) gives graphs showing for selected stations the precipitation for each of the 12 months for each of the 20 years (1895–1914). The amount of precipitation is shown by a dot and the average monthly amounts by heavy lines. The graphs show the seasonal variation of precipitation, and also the variations from the monthly precipitation, which may be expected in different sections. The frequency of subnormal monthly rainfalls can be easily determined. On the Pacific coast the variations are large. East of the Rocky Mountains the variations are, as a rule, largest where the average amounts of precipitation are greatest. East from the Great Lakes the variations are comparatively small.

[6] In connection with this, reference may be made to R. De C. Ward: "Rainfall Types of the United States," Geogr. Rev., vol. 4, August, 1917, pp. 131-144.

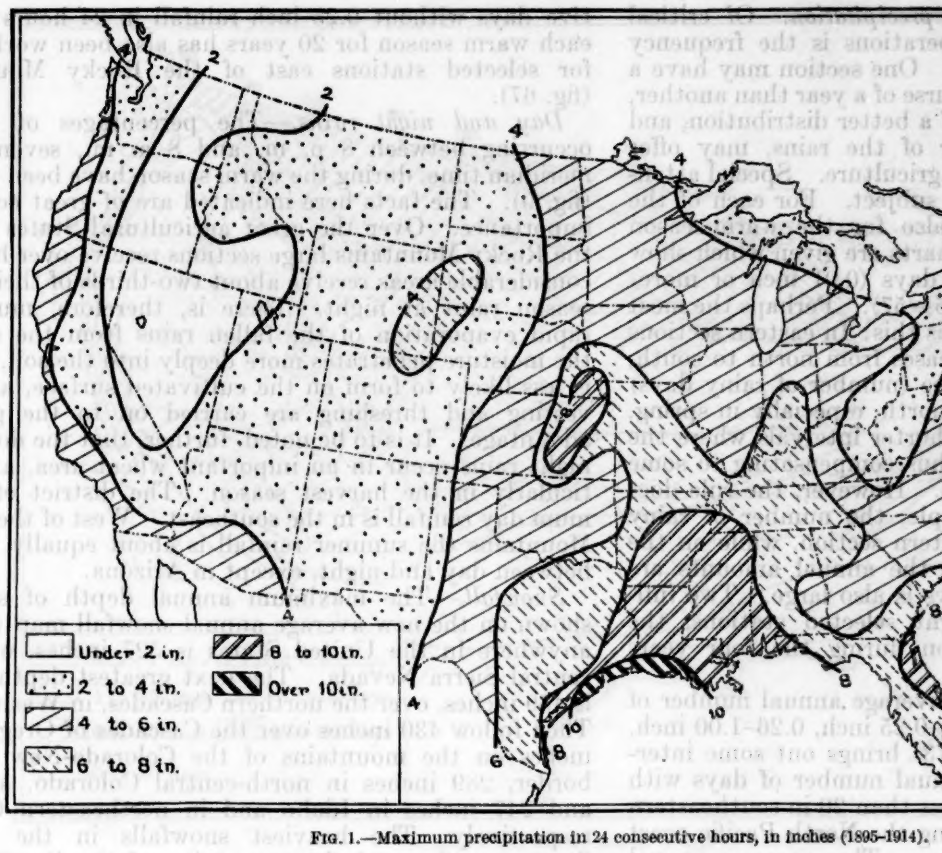

FIG. 1.—Maximum precipitation in 24 consecutive hours, in inches (1895-1914).

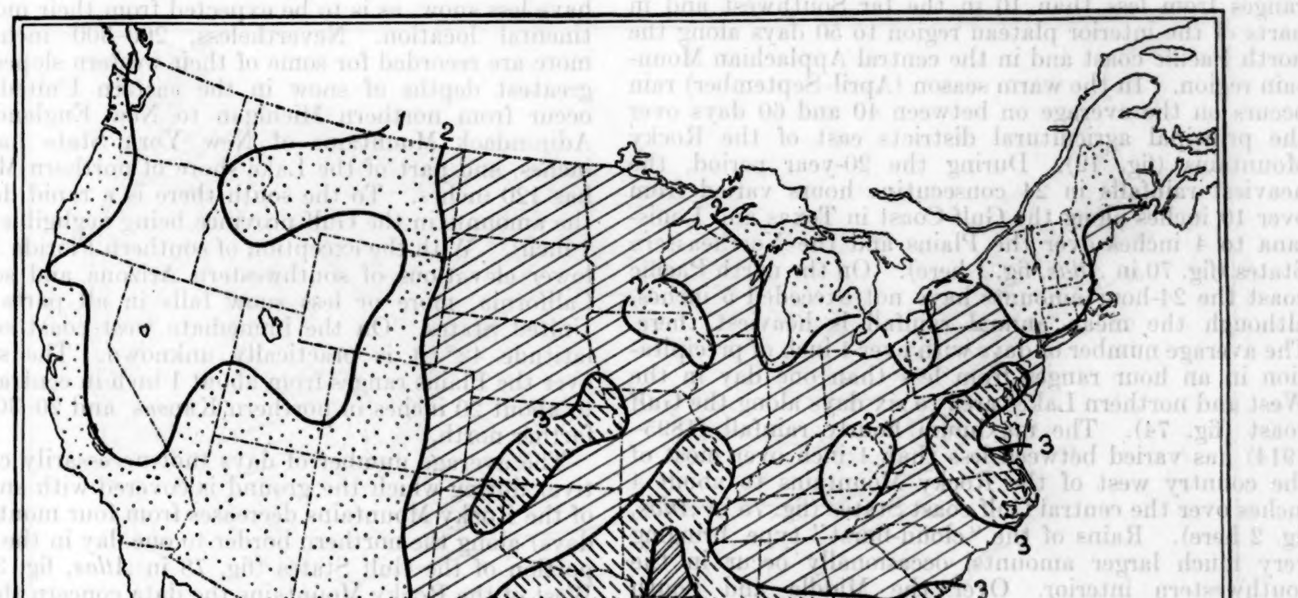

FIG. 2.—Maximum precipitation in one hour, in inches (1895-1914).

Frequency and intensity of precipitation.—Of critical importance in agricultural operations is the frequency and intensity of precipitation. One section may have a good deal less rainfall in the course of a year than another, and yet the former, because of a better distribution, and of a less torrential character of the rains, may offer more favorable conditions for agriculture. Special attention is therefore given to this subject. For each of the seasonal and monthly, and also for the warm-season precipitation charts, smaller charts are given which show the average number of rainy days (0.01 inch or more) (figs. 12, 24, 27, 34–37, 44–47, 54–57). Perhaps the most striking fact here brought out is this: In eastern sections the mean annual rainfall increases from north to south, but the frequency of occurrence (number of rainy days) often increases from south to north; especially in spring. In other words, rain falls at shorter intervals where the total annual amount is less, thus compensating to some extent for the smaller amount. However, the rule does not always work. For example, the number of rainy days is small in the drier western section, while on the northern Pacific coast, where the annual amounts are large, the number of rainy days is also large. Two full-page diagrams show, for eight selected stations, the daily amounts of precipitation during the four years 1911–1914 (figs. 68A, 68B.)

For the whole country, the average annual number of days with precipitation of 0.01–0.25 inch, 0.26–1.00 inch, more than 2 inches (figs. 71–73) brings out some interesting facts. The average annual number of days with *light* (0.01–0.25 inch) rains is less than 20 in southeastern California and reaches 120 along the North Pacific coast and in the upper Lake region. The average annual number of days with *moderate* (0.26–1 inch) precipitation ranges from less than 10 in the far Southwest and in parts of the interior plateau region to 50 days along the north Pacific coast and in the central Applachian Mountain region. In the warm season (April–September) rain occurs on the average on between 40 and 60 days over the principal agricultural districts east of the Rocky Mountains (fig. 12). During the 20-year period, the heaviest rainfalls in 24 consecutive hours varied from over 10 inches along the Gulf Coast in Texas and Louisiana to 4 inches over the Plains and the Northeastern States (fig. 70 in *Atlas*, fig. 1 here). On the north Pacific coast the 24-hour amounts have not exceeded 5 inches, although the mean annual rainfall is heaviest there. The average number of days with over 1 inch of precipitation in an hour ranges from less than one day in the West and northern Lakes area to six days along the Gulf coast (fig. 74). The maximum hourly rainfall (1895–1914) has varied between less than 1 inch over most of the country west of the Rocky Mountains to about 4 inches over the central Gulf coast States (fig. 75 in *Atlas*, fig. 2 here). Rains of the "cloud-burst" type, bringing very much larger amounts, occasionally occur in the southwestern interior. Over the Middle and South Atlantic States and the lower Missouri valley there occurs on the average about once in a season (March–September) a period of 20 or more consecutive days without 0.25 inch of rainfall in 24 hours (fig. 66). Taking the same rainfall amounts and season, but a period of 30 or more consecutive days without 0.25 inch in 24 hours, it is seen that the fewest such drought periods are found in the Middle and South Atlantic States, the Upper Ohio valley, and the northern parts of New York and New England, where they occur on an average about once in three seasons (fig. 69). The longest period of consecutive days without 0.25 inch rainfall in 24 hours during each warm season for 20 years has also been worked out for selected stations east of the Rocky Mountains (fig. 67).

Day and night rains.—The percentages of rainfall occurring between 8 p. m. and 8 a. m., seventy-fifth meridian time, during the warm season have been charted (fig. 9). The facts here indicated are of great economic importance. Over the great agricultural States east of the Rocky Mountains large sections receive over half and considerable areas receive about two-thirds of their warm season rains at night. There is, therefore, much less rapid evaporation of the fallen rains from the surface, the moisture penetrates more deeply into the soil, a crust is less likely to form on the cultivated surface, and harvesting and threshing are carried on to the greatest advantage. It is to be noted, further, that the dominant night rains occur in an important wheat area, and particularly in the harvest season. The district of maximum day rainfall is in the southeast. West of the Rocky Mountains the summer rainfall is about equally divided between day and night, except in Arizona.

Snowfall.—The maximum annual depth of snowfall shown on the new average annual snowfall map (fig. 76) anywhere in the United States is 527 inches, over the central Sierra Nevada. The next greatest depth shown is 459 inches, over the northern Cascades, in Washington. Then follow 430 inches over the Cascades of Oregon, 337 inches on the mountains of the Colorado-New Mexico border, 289 inches in north-central Colorado, and 246 and 247 inches in Idaho and in northeastern Oregon, respectively. The heaviest snowfalls in the United States are those of the mountains of the Pacific coast (400–500 inches in some places). The Rocky Mountains have less snow, as is to be expected from their more continental location. Nevertheless, 200–300 inches and more are recorded for some of their western slopes. The greatest depths of snow in the eastern United States occur from northern Michigan to New England. The Adirondack Mountains of New York State have 150 inches, and part of the Lake shore of northern Michigan has 120 inches. To the south there is a rapid decrease, the amounts in the Gulf province being negligible (under 1 inch). With the exception of southern Florida and the lower elevations of southwestern Arizona and southern California, more or less snow falls in all parts of the United States. On the immediate west coast south of latitude 42° it is practically unknown. The snowfall over the Plains ranges from about 1 inch in central Texas to about 20 inches in northern Kansas, and 20–30 inches farther north.[6]

The average number of days (not necessarily consecutive) during which the ground is covered with snow east of the Rocky Mountains decreases from four months (120 days) along the northern border to one day in the central portion of the Gulf States (fig. 78 in *Atlas*, fig. 3 here). West of the Rocky Mountains the data concern the lower altitudes only. Most of the central Plateau province has from one to two months of snow cover; the northern Pacific coast, less than 10 days; southwestern Arizona, 0 days. A new chart (fig. 79 in *Atlas*, fig. 4 here), gives the average annual number of days on which snow falls (0.01 inch or more, melted). The range is from one day over the Gulf province and the central and southern

[6] In connection with snowfall, reference may be made to the following: Charles F. Brooks, "The Snowfall of the United States," *Quart. Journ. Roy. Met. Soc.*, vol. 39, 1913, pp. 81–84; R. De C. Ward: "The Snowfall of the United States," *Sci. Month.*, vol. 9, 1919, pp. 397–415.

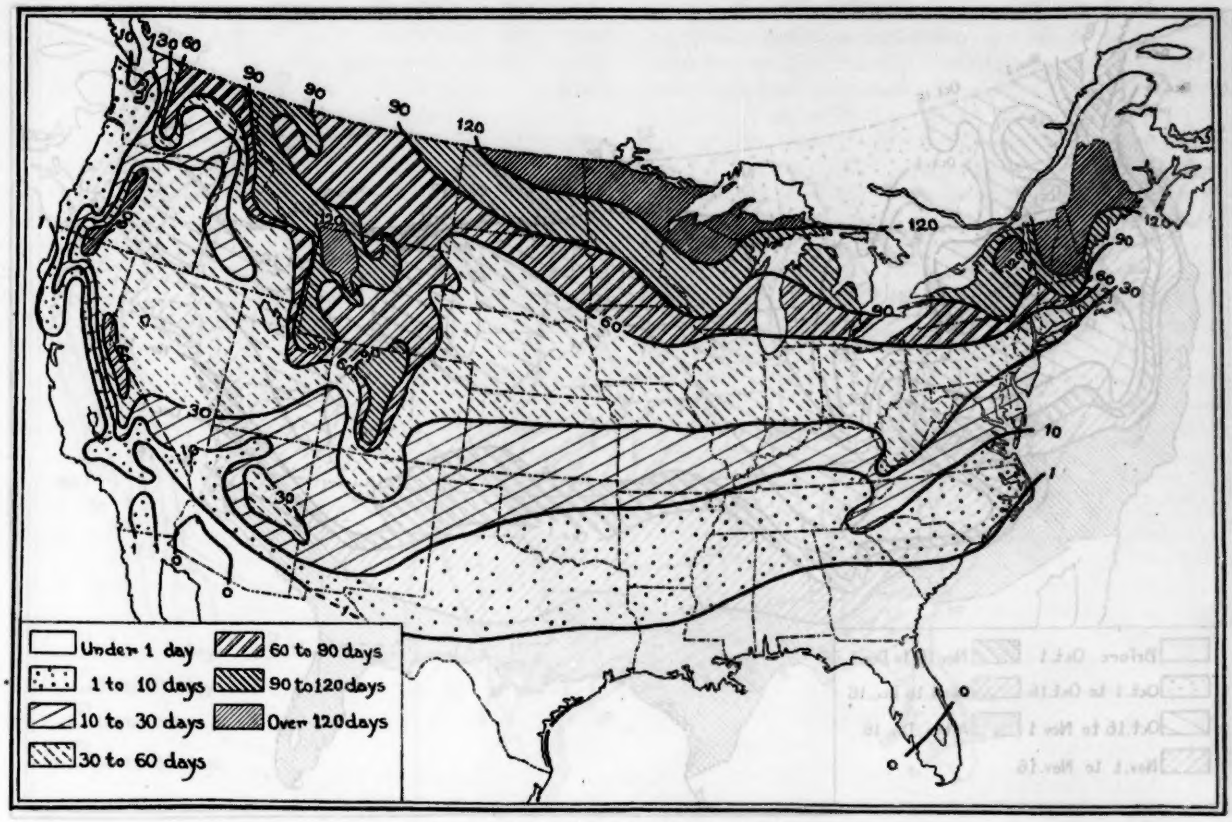

FIG. 3.—Average annual number of days with snow cover.

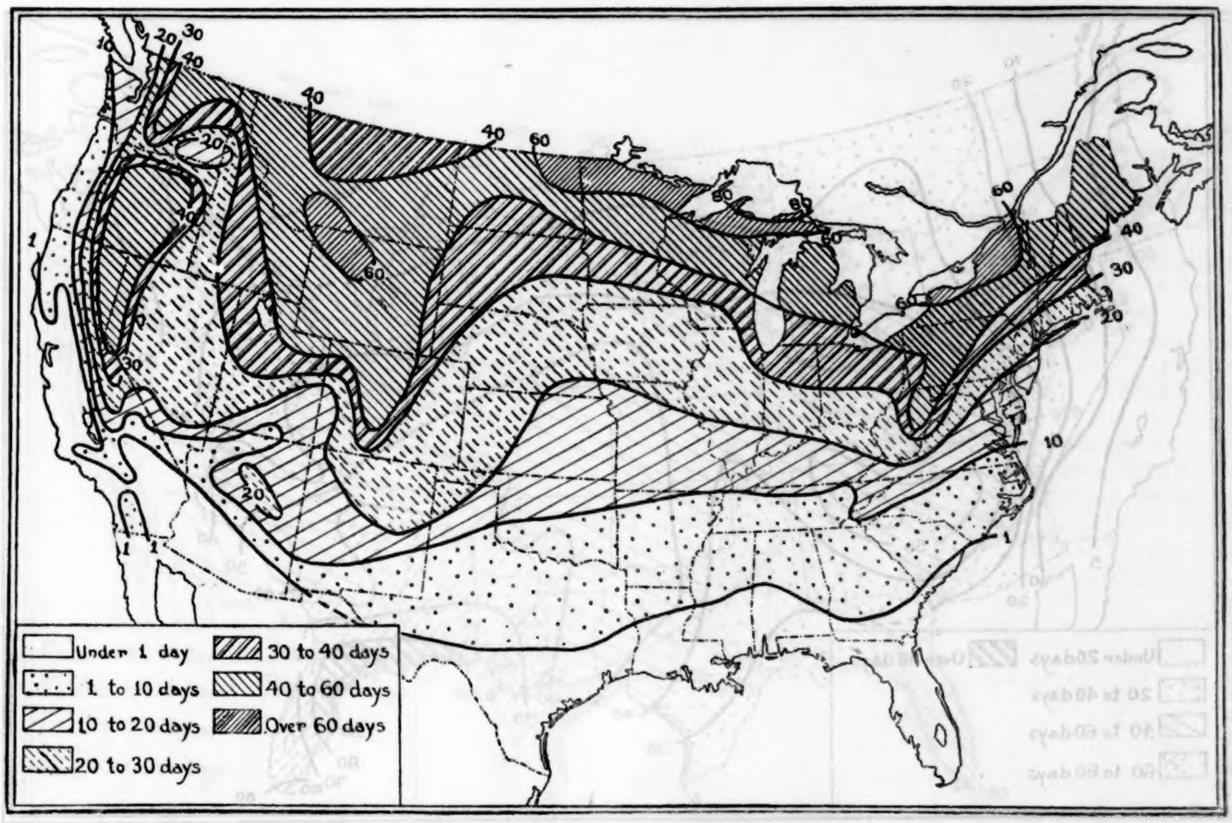

FIG. 4.—Average annual number of days with snowfall (0.01 inch or more, melted).

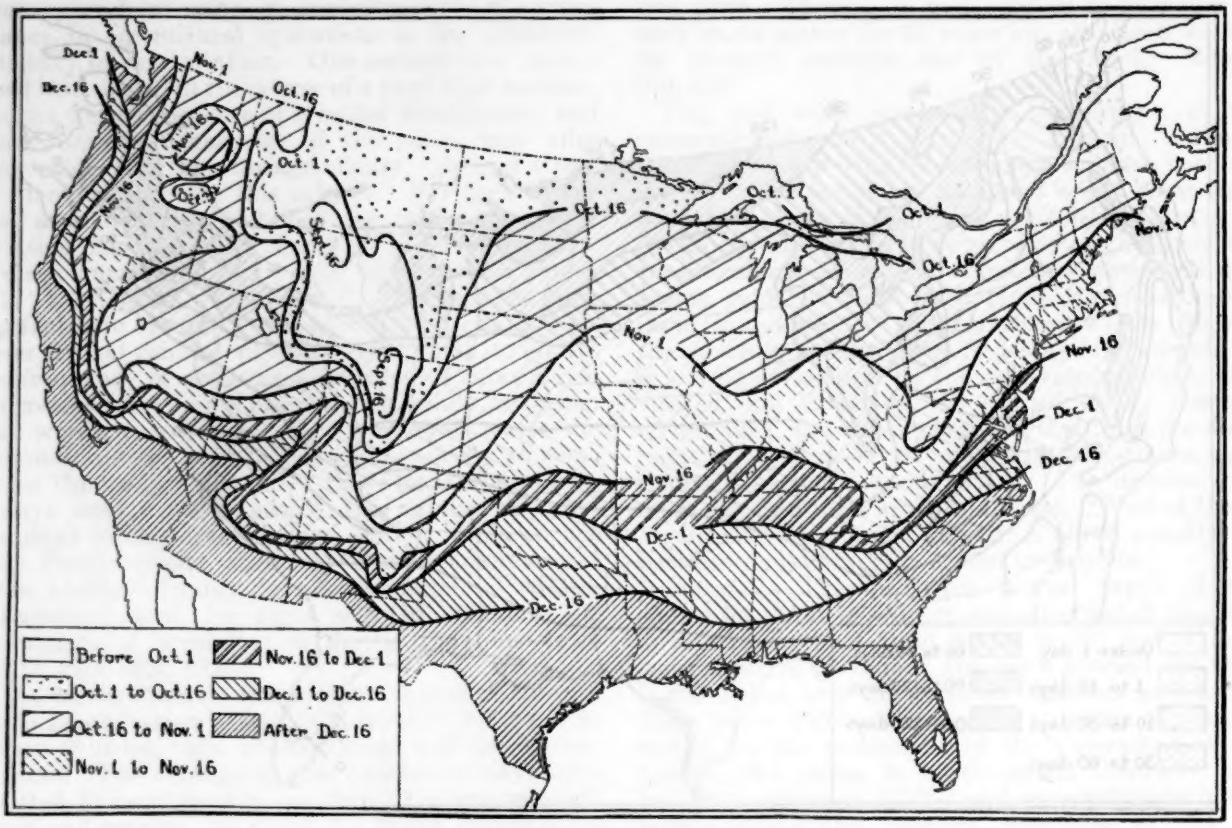

FIG. 5.—Average date of first snowfall in autumn.

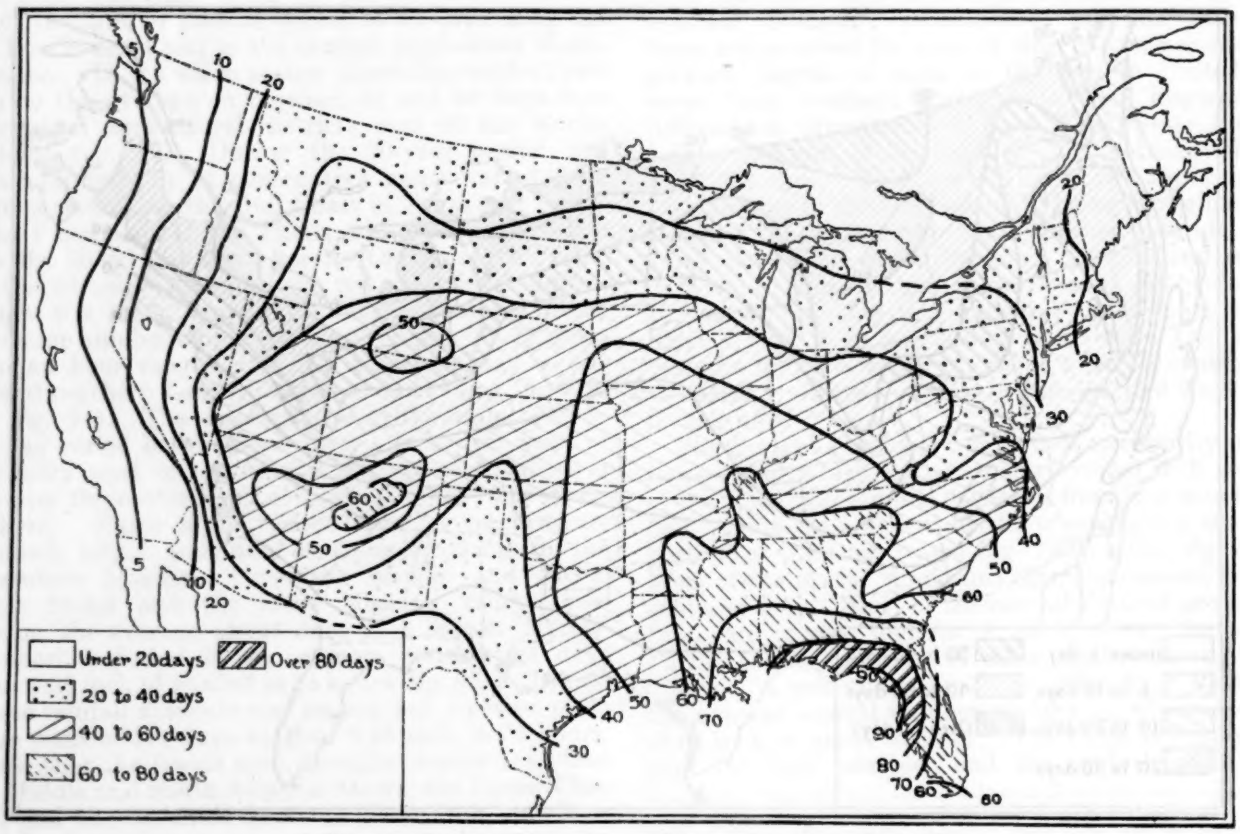

FIG. 6.—Average annual number of days with thunderstorms (1904–1913).

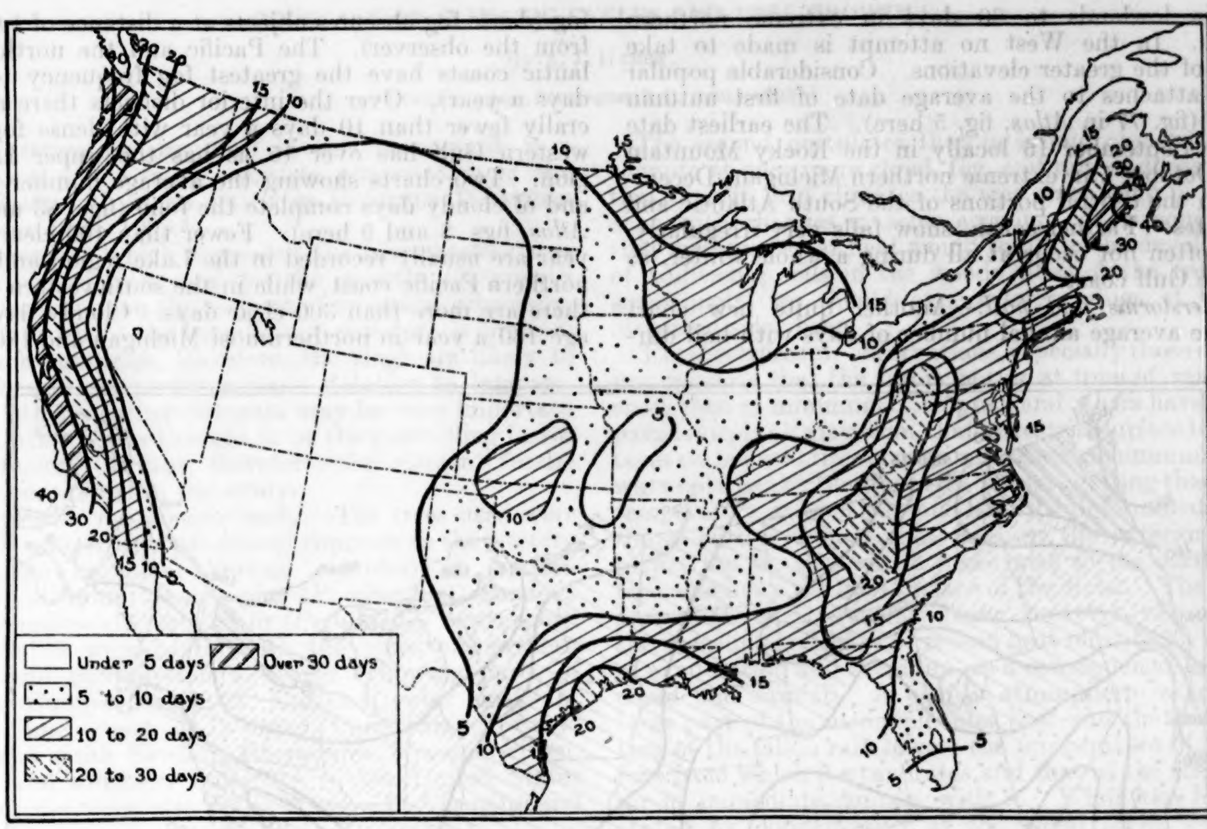

FIG. 7.—Average annual number of days with dense fog (1895-1914).

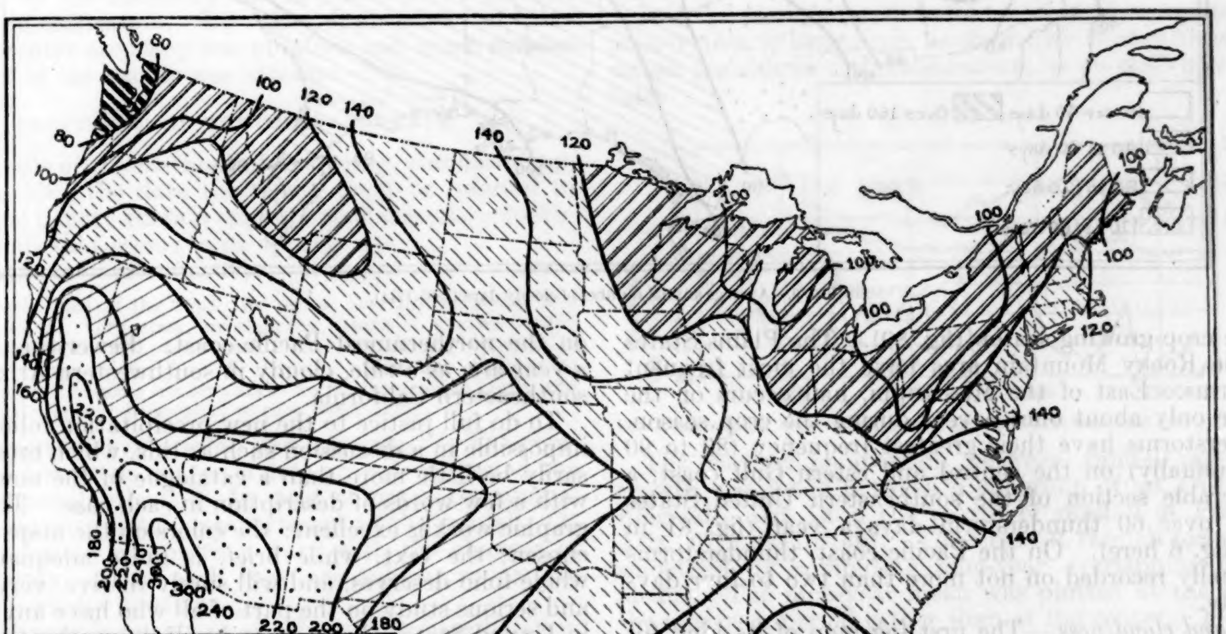

FIG. 8.—Average annual number of clear days (1895-1914).

California lowlands to 80 days in extreme northern Michigan. In the West no attempt is made to take account of the greater elevations. Considerable popular interest attaches to the average date of first autumn snowfall (fig. 77 in *Atlas*, fig. 5 here). The earliest date is before September 16 locally in the Rocky Mountain region; October 1 in extreme northern Michigan; December 16 in the central portions of the South Atlantic and Gulf States. Farther south, snow falls very irregularly, or may often not occur at all during a whole winter, as along the Gulf coast.

Thunderstorms and hail.—Another quite new chart shows the average annual number of days with hail during the crop-growing season (fig. 80). The Plains States and the Rocky Mountain area have the most frequent hailstorms. East of the Mississippi, hail occurs on the average only about once a year during the crop season. Thunderstorms have their greatest frequency (80 to 90 days annually) on the central and estern Gulf coast, a considerable section of the southeastern United States having over 60 thunderstorm days a year (fig. 81 in *Atlas*, fig. 6 here). On the Pacific coast, thunderstorms are usually recorded on not more than two to four days annually.

Fog and cloudiness.—The first fog map of its kind for the United States (fig. 82 in *Atlas*, fig. 7 here) gives the distribution of the average number of days with dense fog (dense fog obscures objects at a distance of 1,000 feet from the observer). The Pacific and the northern Atlantic coasts have the greatest fog frequency (over 40 days a year). Over the interior districts there are generally fewer than 10 days a year with dense fog. The western Gulf has over 15, as has the upper Lake region. Two charts showing the average number of clear and of cloudy days complete the folio (figs. 83 and 84 in *Atlas*, figs. 8 and 9 here). Fewer than 100 clear days a year are usually recorded in the Lake region and on the northern Pacific coast, while in the southwestern interior there are more than 300 clear days. Cloudy days average 160 a year in northernmost Michigan and 180 a year on the northernmost Pacific coast. Fewer than 20 days a year are, as a rule, cloudy in southwestern Arizona and southeastern California.

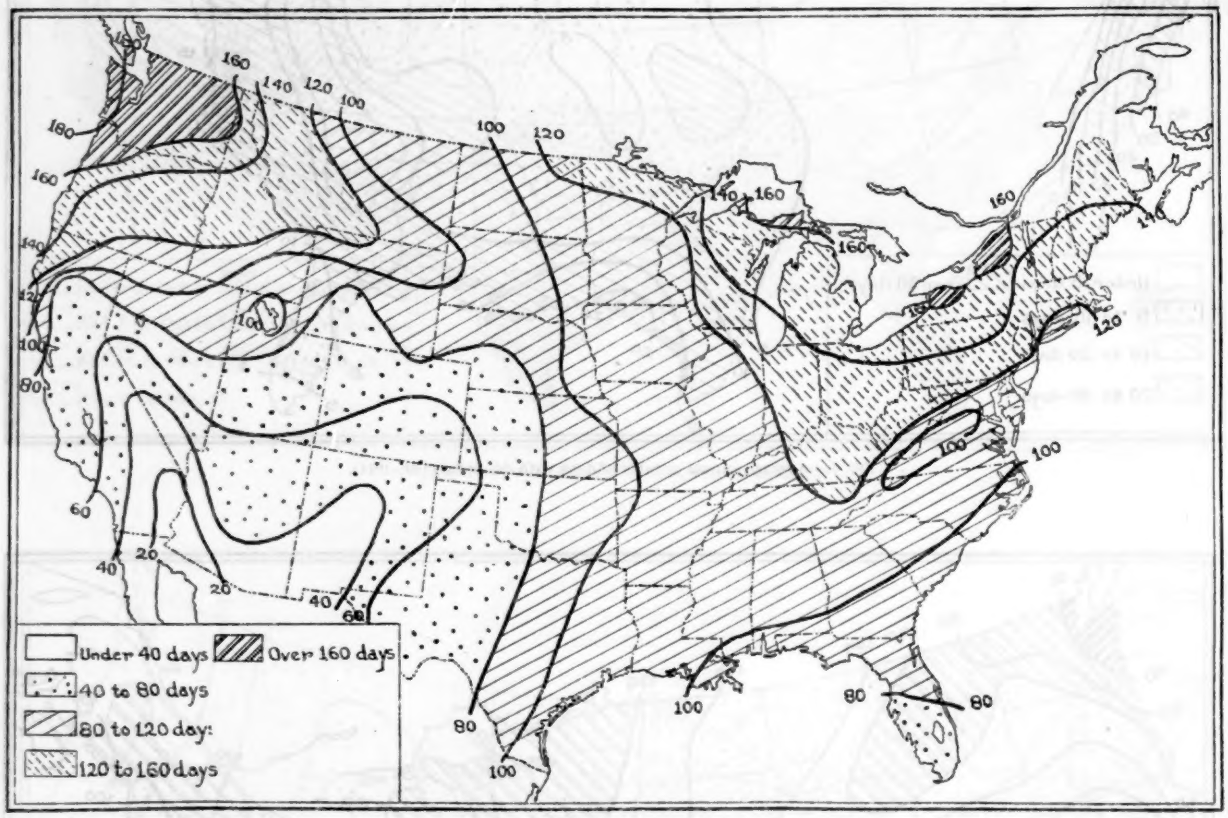

FIG. 9.—Average annual number of cloudy days (1895–1914).

To do full justice to the new precipitation folio is quite impossible in a discussion such as this, which must necessarily be little more than a catalogue of the new charts, with a few words of description in each case. The cartographic work is excellent; the colors on the maps are well chosen; the text, while brief, is quite adequate. The whole folio deserves, and will surely receive, very careful and serious study on the part of all who have any interest in United States climates, and will do much to establish American climatology on a higher plane of scientific accuracy.

DOUGLASS ON CLIMATIC CYCLES AND TREE-GROWTH.[1]

By A. J. HENRY.

[Weather Bureau, Washington, D. C., April 1, 1922.]

The investigation described in this monograph is a continuation and a more complete presentation of the subject dealt with in an article in MONTHLY WEATHER REVIEW for June, 1909.[2]

The argument which suggested the investigation was (1) the rings of trees measure the growth; (2) growth depends largely upon the amount of moisture, especially, in a climate where the quantity of moisture is limited; (3) in such countries, therefore, the rings are likely to form a measure of precipitation. Relation to temperature and other weather elements may be very important but precipitation was thought to be the controlling factor in this region. It was, therefore, the element fundamentally considered in the study.

Trees suitable for climatic study.—The trees used were the yellow pine (*Pinus ponderosa*) common to the western Rockies; the sequoias (*Sequoia gigantea*) of central-southern California; Scotch pine (*P. silvestris*); hemlock (*Tsuga canadensis*); Douglas fir (*Pseudotsuga mucronata*).

The studies were begun with the pines of northern Arizona and carried thence to the following parts of northern Europe; South of England; outer coast of Norway, inner coast of Norway, Christiana, Norway; central and south Sweden; Eberswalde, Prussia, Pilsen, Austria, and southern Bavaria. In the United States measurements were also made of trees in Vermont and Oregon.

The details of counting the rings used in the preliminary studies were improved as the investigation proceeded, especially by the discovery and application of a method of cross-identification. By the application of this method greater accuracy was obtained and much greater confidence in the results was attained.

TREATMENT OF THE MEASUREMENTS.

For details of the methods of averaging, standardizing, and smoothing the data the reader must be referred to the original paper; there is one comment as to the smoothing methods that seems to be appropriate.

The author remarks (p. 61):

> In the early part of the work the use of overlapping means was adopted. At the very start, overlapping means of a considerable number, such as 11 or 9, were used. This was quickly changed to overlapping means of 3. * * * However, this was changed to Hann's formula [3] because his formula is normally easier to apply and it gives a little more individuality to each observation.

Correlation between rainfall and tree growth.—The completion of numerous curves of tree growth suggested the following possibilities: (1) In arid climates the annual rings are approximately proportional to the rainfall; (2) in moist-climate groups they vary with the changes of solar activity; (3) in each they are subject to certain cycles or periodic variation.

The reviewer is unable to closely differentiate between 1 and 2 of the above. The first proposition is logical and seems to be well established, at least for northern Arizona. The second postulates that in humid climates which connote at once more cloud, fog, and rain and less insolation than in arid climates the tree rings vary in accordance with changes in solar activity. It is conceivable that increased solar heat would result in the development of additional cells in the woody fiber of the tree, and, accordingly, we should expect larger rings at time of increased solar heat.

The spectroscopic observations, especially those of Lockyer, indicate that the sun is hotter at time of maximum spots than at minimum. Köppen and others have shown, paradoxical as it may seem, that terrestrial surface temperatures are lower at time of maximum than at minimum. This was explained by Blanford (1875) by suggesting that the air temperature at land stations must be determined not by the quantity of heat that falls on the exterior of the planet but by that which penetrates to the earth's surface, chiefly to the land surface of the globe. The greater part of the earth's surface being, however, one of water the immediate effect of increased heat must be an increase of evaporation and therefore, as a consequence, increased cloud and rainfall. A cloudy atmosphere intercepts a large part of the incoming solar heat and the reevaporation of the fallen rain lowers the temperature of the surface from which it evaporates and that of the stratum of air in immediate contact with it. While the heat liberated by condensation at the cloud levels doubtless prevents cooling at those levels, yet other causes are at work which tend to depress the air temperature at the surface.

It is therefore not easy to find a physical reason for the solar rythm in tree rings, as shown by Doctor Douglass, unless possibly in the precipitation, as we shall point out later.

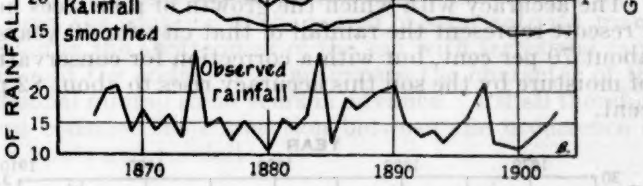

FIG. 1.—Correlation between tree growth and rainfall in smoothed curves: Flagstaff.

The earliest comparison between rainfall and tree growth was made between a subgroup of six trees near Flagstaff, Ariz., and the record of rainfall at Prescott, Ariz., 67 miles distant. The Prescott rainfall record was smoothed by computing nine-year overlapping annual means. The nine-year mean was plotted at the end of the nine-year period rather than at the center. Figure 1 (No. 13 of original) above gives smoothed curves of rainfall and tree growth at the top and the observed rainfall at the bottom.

The rainfall at Prescott for the whole years 1867, 1868, 1869, 1874, and 1875 is missing from the record; the missing records were supplied by the author as follows:

> The Prescott gaps were bridged by plotting the rainfall curves of all records near Prescott and at similar altitudes in Arizona or western New Mexico, and finding enough similarity in many of them to Prescott to make a fair estimate of the actual precipitation at Prescott in the lacking years.

[1] Carnegie Institution of Washington, *Publication No. 289.*

[2] Weather cycles in the growth of big trees. See other papers by the same author as follows: Method of estimating rainfall by the growth of trees, *Bull. Amer. Geograph. Soc.*, XLVI:321–335. A photographic periodogram of sunspot numbers, *Astroph. Jour.* XL, No. 3:326–331. A method of estimating rainfall by the growth of trees. The climatic factor as illustrated in arid America, by E. Huntington, *Carnegie Inst. Wash.*, *Pub. No. 192*, Chap. I:101–121. Climatic records in the trunks of trees, *Amer. Forestry*, December, 1917, 732–735. An Optical Periodograph, *Astrophys. Jour.*, XLI:173–186, Evidence of Climatic Effects in the Annual Rings of Trees, *Ecology*, I:24–32.

[3] In a letter to the reviewer the author makes it plain that the expression "Hann's formula" refers to the familiar method of Bloxam as described in *Quar. Jour. Roy. Met. Soc.* 30:95, viz, $b=(a+2b+c)/4$.

The comparison shown in Figure 1 was made because at that time there were not enough rainfall observations for Flagstaff to be of service. Later, when a Weather Bureau station had been in operation for several years, a direct comparison, as shown in Figure 2 (No. 14 of original), was made.

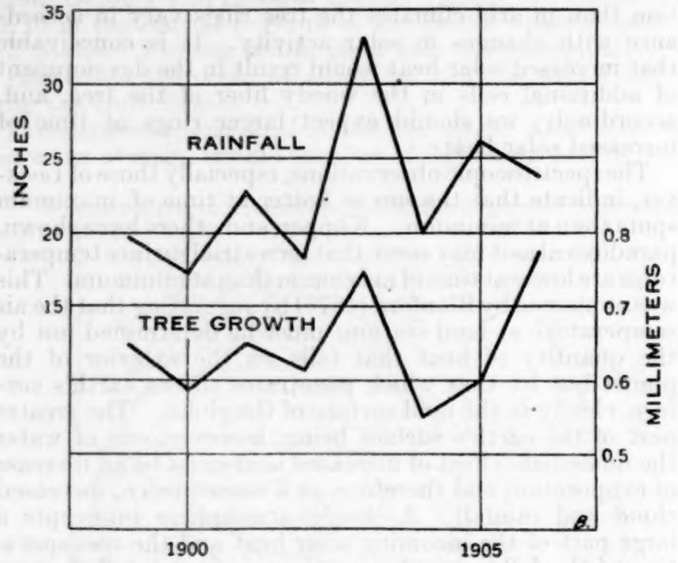

FIG. 2.—Early test of correlation between tree growth and rainfall by years: Flagstaff.

In the above Figure 2 the agreement is remarkably close and there is apparently very little, if any, lag between the occurrence of precipitation and response in tree growth.

The Prescott correlation.—Five subgroups, numbering in all 67 trees located at different points in the vicinity of Prescott, were used. These all cross-identified among themselves both as individuals and as groups with entire success, but in comparison with Prescott rainfall they differed greatly, the group nearest the city showing the best accordance. This group No. V has been plotted to form Figure 3 (No. 7 of original). The rainfall and tree-growth data are both presented unsmoothed.

The accuracy with which the growth of pine trees near Prescott represent the rainfall of that city for 43 years is about 70 per cent, but with a correction for conservation of moisture by the soil this accuracy rises to about 82 per cent.

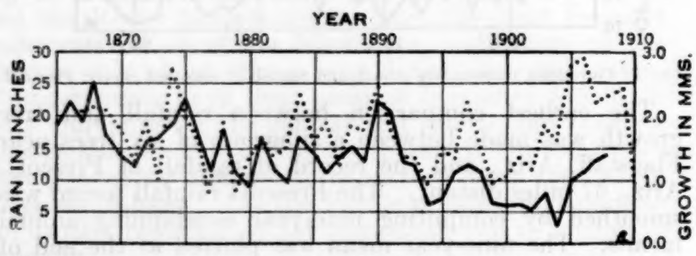

FIG. 3.—Annual rainfall and growth of trees, Group V, at Prescott. Dotted line, rainfall; solid line, tree growth.

In the reviewer's opinion the effect of the conservation of moisture in the dry soil of an arid region would be very difficult of evaluation, except for very favorable and exceptional conditions of soil and local topography. Continuous precipitation and stream-flow measurements in the Wagon Wheel Gap, Colo., watersheds seem to indicate that the conservation of water due to excess of precipitation in any season does not persist much, if any, beyond 8 or 10 months. The author very properly reserves the subject of the moisture content of the soil for further study.

Sequoia correlation with rainfall.—Attempt is made to compare the growth of sequoias with the rainfall of Fresno and San Francisco. The difficulty inherent in this comparison was probably realized by both Huntington and Douglass. The best that can be said of the rainfall of Fresno is that it is the only record available.

The rainfall record of Fresno does not begin until 1882. The San Francisco record, while it began in the early fifties, represents a different rainfall régime from that of Fresno—a station of the Great Valley of California. It is not strange, therefore, that the agreement between the two curves is not as good as at Prescott.

CORRELATION WITH SUN SPOTS.

Under this caption the author remarks (p. 74):

The differential study of the Arizona trees will be taken up in connection with cycles, but can be summarized in the statement that in the last 160 years 10 of the sun-spot maxima and minima have been followed about four years later by pronounced maxima and minima in the tree growth. Also, during some 250 years of the early growth of these trees, they show a strongly marked double-crested 11-year variation.

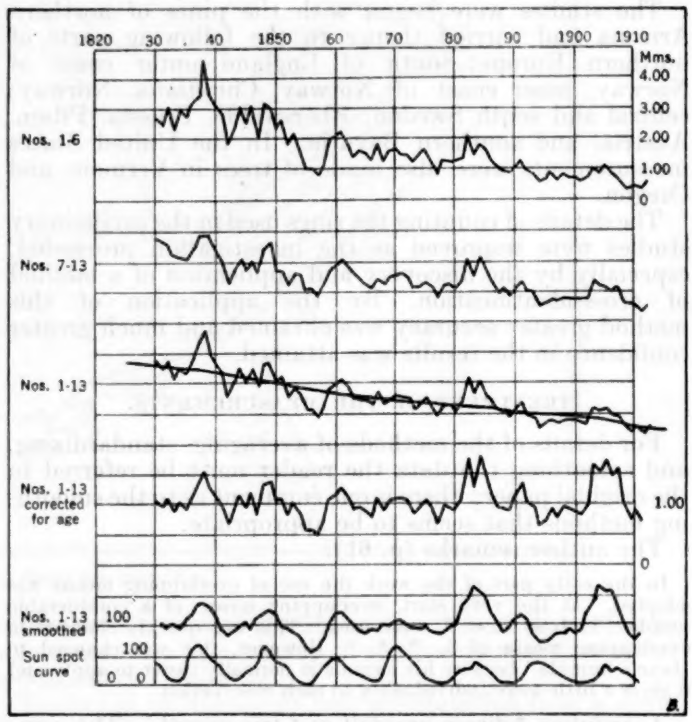

FIG. 4.—Sun spots and growth of trees at Eberswalde, Germany.

The above refers to dry climate reactions; the wet climate reaction is different, as witness the following extract:

Wet climate reaction.—In the very first group of continental trees studied, those of Eberswalde near Berlin, the remarkable fact was recognized at once that 13 trees from one of those carefully tended German forests show the 11-year sun-spot curve since 1830 with accuracy. * * * The other trees of that group do not show quite so perfect rhythm as do the marked radii shown, but are like the other parts of these sections, showing strongly a majority of the maxima. Taking the group as a whole, the agreement is highly conspicuous, and the maximum growth comes within 0.6 year of the sun-spot maxima. The Eberswalde curves arranged in two groups and compared with the sun-spot curve are shown in Figure 4 (No. 9 of original).

An explanation of the increased tree growth at Eberswalde may be found in a consideration of the precipitation record for Berlin. I have taken the five epochs of

sun-spot maximum centering about 1860, 1870, 1883, 1894, and 1906 and computed the annual rainfall departure for the central year and the single year immediately preceding and following; thus the years 1859, 1860, and 1861 would represent the epoch of spot maximum of 1860. Four out of the five epochs were, on the average, periods of more than normal rainfall and but one, that of 1894, was a time of deficient precipitation. Casual inspection of the precipitation record for Berlin discloses the fact that in the 60 years 1848–1907 there were more wet than dry years, a condition directly contrary to that which is the rule in the United States, but whether this condition is common to northern Europe is not at this time known.

The concluding chapters of Dr. Douglass's work are devoted to a discussion of "Methods of Periodic Analsis," "Cycles" with an appendix giving tables of mean tree growth extending back to 1306 B. C. The book should be read by all students of weather periodicities.

CLEMENTS ON DROUTH PERIODS AND CLIMATIC CYCLES.[1]

By A. J. HENRY.

[Weather Bureau, Washington, D. C., April 1, 1922.]

Dr. Clements refers briefly to the work of Douglass[2] in relating the annual rings of trees to rainfall and the sun-spot cycle as suggesting the possibility of using the latter for forecasting the rainfall from year to year.

He also adds, seemingly in confirmation of Douglass's work, the statement that "practically all the groups of trees studied gave a clear record of growth cycles corresponding closely to the sun-spot cycle. They confirmed the hypothesis that years of sun-spot maxima were generally marked by deficient rainfall, and those of sun-spot minima by rainfall above the normal."

A preliminary examination of the rainfall records of the States west of the Mississippi River showed that the two major drouth periods of 1893–1895 and 1870–1873 coincided with sun-spot maxima. It was also evident that abundant precipitation had occurred frequently, if not regularly at times of sun-spot minima and from these facts the inference was drawn that the spot minimum of 1913 would be accompanied by an excess of rainfall and that the spot maximum of 1917 would likewise be associated with a deficit in the rainfall. Partial confirmation of these inferences led the author to make the following statements:[3]

> The most attractive and promising feature of the summer's work has been the checking and tracing of the course of the present climatic cycle. The second recorded absolute minimum of no sun spots occurred in 1913 and served as the focus of a period of exceptional rainfall in the West. The drouth of the present summer (1916) in the Western and Mountain States suggests the beginning of the dry phase of the cycle. Its effect upon the carrying capacity of the ranges and upon the production of dry farms has been critical. Whether it be followed by the full period of several dry years or not, it has furnished further confirmation of the fact that all grazing and dry farming must be based upon the recurrence of dry periods; in both a scientific system of expansion and contraction must be devised to prevent disaster during dry years. If the next two or three years prove to be dry in harmony with the maximum of the sun-spot cycle, the possibility of anticipating dry seasons will be greatly enhanced. In the field of forestation much evidence has been obtained to show that planting is successful only during wet phases and that natural reproduction occurs practically only during such phases.
>
> The investigations of climatic cycles has been continued from both the biological and astronomical approach. The former gains interest from the fact that the years 1916, 1917, and 1918 have in general been years of drouth in the West and especially the Southwest. This was suggested as a probability upon the approach of the sun-spot maximum in 1916. The maximum was passed in 1917 and attention is now centered upon the expected increase of rainfall generally as the sun-spot minimum is approached during the next four or five years. It is proposed to follow the biological effects as seen in growth, reproduction, and abundance as closely as possible and to correlate these with the climatic phases. Striking evidence of these effects have been obtained during the drouth of the past two years. By far the most important problem, however, is the relation of the sun-spot cycle to the climatic and growth cycles. There appears to be little question of the usual coincidence of these three cycles, but the existence of a causal relation is still in doubt. In the endeavor to make use of the sun-spot cycle to anticipate climatic changes, this matter is of paramount importance.[4]

The remainder of the article is devoted to an examination of the rainfall records of 23 States west of the Mississippi in an effort to establish a basic relation between rainfall and the spottedness of the sun. The method of collating the rainfall records was as follows: In the 23 States there were 323 rainfall records in 1881 and more than 1,300 in 1919. For the seventies the number was less than 100—76 in 1869, and for earlier years still less. The yearly departures of the annual totals from the normal were tabulated and classed as positive or negative by years, or rather by groups of five years, the central year of each group being the year in which the epoch of maximum sun spots occurred. The groups, therefore, center about the years 1837, 1848, 1860, 1871, 1883, 1894, 1907, and 1917. Concerning these epochs of maximum, Doctor Clements further remarks:

> Since the beginning of observations in 1750 the yearly number of sun spots at the maximum has varied from 46 to 154, though the number has fallen below 80 for but 5 of the 16 maxima. For the 8 maxima considered here, the number of spots falls below 80 only in 1907[5] and 1883, when the numbers were 62 and 64, respectively. In other words, 6 of the maxima lie above 77; i. e., half the number of spots for the highest maximum, 154.

DISCUSSION.

The chief interest in Doctor Clements's paper is, of course, the coupling of the period of solar activity manifested in the spottedness of the sun with terrestrial rainfall and the endeavor to anticipate the character of the seasonal rainfall some years in advance. I shall therefore first consider the connection between the occurrence of sun spots and rainfall.

SUN-SPOT RAINFALL RELATIONS.

Since Meldrum, in 1872, called attention to the possible connection between the phenomena above mentioned, much discussion has arisen or, rather, many persuasive reasons have been adduced in support of the idea that there must be a basic connection between the two events. It is scarcely necessary to analyze the large literature on the subject already available, but it will be desirable to touch upon the several stages of the arguments which have been advanced in support of the hypothesis.

The effort to relate sun spots with terrestrial weather dates back many years, but the specific attempt to show a relation between sun spots and *rainfall* is of comparatively recent origin. The discovery of what is popularly

[1] *Ecology*, Vol. II, No. 3, July, 1921.
[2] Mo. WEATHER REV. 37: 225-236 and abstract of a later work in this REVIEW, immediately preceding.
[3] Carnegie Inst. Wash. Pub. No. 242, 1916.
[4] Loc. cit., pub. 304, 1917.
[5] According to Wolfer, the epoch of maximum at this time occurred in 1906.4, and the maximum number of spots was 64.2 (smoothed) in February. The epoch of 1883, according to the same authority, occurred 1883.9, and the maximum number of spots was 74.6 in November of that year.

known as "Brückner's [6] long period climatic oscillations of 35 years" in 1890 led to renewed efforts to connect these oscillations with solar activity.

Brückner himself investigated the subject, and although he was not successful in establishing a relation, yet he felt that such a relation must really exist, even if it does not appear in sun-spot data.

The following is a résumé of the literature on the precipitation sun-spot relations to the end of 1917.[7]

VARIATIONS IN PRECIPITATION AND SUN SPOTS.

The relation between the variations in the precipitation and the sun spots has led to many investigations since Meldrum in the year 1872 showed for several tropical stations that the rainfall varies directly as the sun spots, so that a maximum of rainfall occurs at the maximum of sun spots, and vice versa. Sir Norman Lockyer showed this also for several stations in Ceylon and in India. Investigations of Symons and Jelinek indicated the same conclusion, that more rain falls at sun-spot maximum than at sun-spot minimum, but it appeared that the periodicity is most marked and regular in the tropical regions. Hahn pointed out that in the period from 1820 to 1870 dry summers were most prevalent during the time of increasing sun-spot numbers. On the whole, the investigations on the relation between precipitation and sun spots are very conflicting and have led to more or less doubtful results. Meteorologists have here, as in most similar investigations, made the error of assuming that the same cause should everywhere produce the same effect, without taking sufficiently into consideration that the same cause at different places may act oppositely. Archibald and Hill have independently shown that the winter rain in India has the opposite course to that which Meldrum found. They obtained, in fact, a minimum at the maximum of sun spots and a maximum of winter rain about at the time of the minimum of sun spots. On the other hand, Hill seeks to show that the Indian summer monsoon rain has a great tendency to vary in coincidence with the sun spots in this manner that an excess of precipitation occurs in the first half of the cycle after the sun-spot maximum, and vice versa, but on the whole the curves show little agreement. Blanford came meanwhile to the conclusion (1889) that the precipitation in India on the whole gave no sure indication of a 10 or 11 year period for the last 22 years.

For Europe, the connection between precipitation and sun spots has also been investigated. (See Schreiber (1896, 1903), A. Buchan (1903), and others.) P. Schreiber (1896, 1903) found a probable 11-year period in the precipitation at different stations in Europe, but with two maxima, one, two years after sun-spot maximum, the other at the time of sun-spot minimum, and with two minima, one coincident with sun-spot maximum and the other three years after the sun-spot minimum.

A. Buchan (1903) found a double period in the precipitation in Great Britain, so that a minimum occurs shortly after sun-spot minimum and another shortly after sun-spot maximum. The first and weaker maximum is much less marked in Scotland and west Europe than in southeast England where the principal maximum occurs nearer the sun-spot maximum.

G. Hellmann (1909) has investigated the relation of variation of precipitation in different parts of Europe to the sun-spot period and finds that there is no universally followed rule about it. In most cases of the stations examined by him there occur within a sun-spot period two maxima of rainfall which occur about six or five years from one another. At the time of sun-spot minimum there occurs at most stations a maximum of rainfall, but in consequence of the progress of wet and dry years from south toward north, in western Europe the maxima and minima of precipitation tend to be progressively displaced in the sun-spot cycle.

The subdivision of the 11-year period of rainfall Hellmann explains by an assumed double influence of the variation in the solar radiation during the sun-spot period. First is a direct influence arising from the equatorial region and acting indirectly as an influence upon the place itself. Hellmann proceeds from the assumption, now proved erroneous, that at the time of sun-spot minimum there is a greater radiation of the sun that at the time of sun-spot maximum. This increased radiation, he thinks, would act principally in the equatorial regions of the earth to produce an increase of temperature, evaporation, and precipitation, and thereby would increase the energy of the total circulation of the atmosphere. This equatorial influence would be delayed in reaching the higher latitudes. But, on the other hand, the direct influence on the precipitation in these latitudes themselves due to the sun spots would be considerably weaker than in the equatorial regions. The impulses derived, respectively, in the equatorial regions and in places of higher latitude would exercise together either a cumulative or an interfering action. It would be therefore conceivable, he thinks, that in one place the minimum of rainfall would be associated with maximum of sun spots, while in another place the opposite association would prevail.

E. H. Chapman[8] has collected correlation coefficients between sun spots and rainfall for 147 places scattered over the globe. The value of the coefficient of correlation r, ranges from zero to ± 0.50 and there are but two cases where r equals or exceeds 0.50, viz, for Edmonton, Canada, -0.50, and Bathurst, Gambia, $+0.51$. In both cases the records of rainfall were relatively short. In the great majority of cases the magnitude of r was not great enough to be of significance.

Notwithstanding the failure to establish any definite relation between sun spots and rainfall, the opinion is held by some that a real relation subsists; for example, Prof. W. H. Pickering,[9] in discussing droughts of Jamaica; concludes:

The 13 droughts have occurred on the average at intervals of 4.17 years. If their relation to the sun spots was due merely to chance the average deviation should be one-fourth of this, or 1.04 year. Not one of the deviations in Table 6 reaches this figure. From this we conclude, considering the inevitable errors occurring in fixing the exact dates of sun-spot maxima and minima, that a real relation subsists between these dates and those of Jamaica droughts.

RAINFALL DATA OF TABLE 1.

I now pass to a consideration of the rainfall data as presented in Dr. Clements's Table 1.

[6] E. Brückner, Klimaschwankungen seit, 1700, Vienna, 1890.

[7] Temperature variations in the North Atlantic Ocean and in the atmosphere, Björn Helland-Hansen and Fridtjof Nansen, Smithsonian Mis. Coll., vol. 70, No. 4, 1920.

[8] Chapman, E. H., The Computers Handbook M. O. Section V, Computations related to the theory of probabilities, pp. 108-111.

[9] Pickering W. H., The relation of prolonged tropical drouths in Jamaica to sun spots. Mo. WEATHER REV. 48:589.

TABLE 1.—*Number of rainfall stations in the groups and years named that had positive and negative annual rainfall departures, respectively.*

[The figures in the top line of each group are positive, those in the second line negative, and those in the third line are the algebraic sum of the two preceding.]

Sun spots	54	58	65	63	51	70	84	79	61	43	59	60	56	51	41	46	59	96	83		Number.	Years.
Years	1881	1882	1883	1884	1885	1892	1893	1894	1895	1896	1905	1906	1907	1908	1909	1915	1916	1917	1918	1919	+	−
Group 1	37	25	7	87	19	99	105	158	71	191	97	284	249	31	250	1,185	176	34	68	54	......	......
	65	80	97	20	95	97	91	66	153	50	220	35	77	304	25	78	62	188	186	204	......	......
	−28	−55	−90	+67	−76	−2	+14	+92	−82	+141	−123	+249	+172	−273	+225	+107	+114	−154	−118	−150	9	11
Group 2	19	23	15	37	15	29	35	43	21	55	82	103	107	83	100	73	87	33	66	67	......	......
	22	16	21	4	26	49	48	51	80	42	56	26	27	53	29	52	28	101	68	90	......	......
	−3	+7	−6	+33	−11	−20	−13	−8	−59	+13	+26	+77	+80	+30	+71	+21	+59	−68	−2	−23	10	10
Group 3	11	8	5	15	11	35	23	32	77	51	119	166	110	99	134	123	88	28	122	128	......	......
	6	17	11	5	14	62	76	71	43	75	61	49	114	119	61	42	84	157	85	118	......	......
	+5	−9	−6	+10	−3	−27	+53	−39	+34	−24	+58	+117	−4	−20	+73	+81	+4	−129	+37	+10	11	9
Group 4	82	76	80	75	60	153	74	17	45	227	311	215	215	194	348	300	185	60	153	234	......	......
	20	27	23	31	56	51	169	255	260	107	81	172	152	196	54	52	176	321	206	132	......	......
	+62	+49	+57	+41	+4	+102	−95	−238	−215	+120	+230	+43	+63	−2	+294	+248	+9	−261	+653	+102	14	6
Group 5	30	29	34	33	34	95	15	41	100	157	302	234	128	262	174	332	104	28	200	256	......	......
	31	25	16	21	22	82	185	180	138	102	44	115	222	104	219	59	299	399	219	149	......	......
	−1	−4	+18	+12	+12	+13	−170	−139	−38	+55	+258	+119	−94	158	−45	+273	−195	−371	−19	+107	10	10
Total	179	161	141	247	139	411	252	291	314	681	911	1,002	809	669	1,006	1,013	640	183	609	739	......	......
	144	165	168	84	213	341	569	623	674	376	462	397	592	776	388	283	649	1,166	764	693	......	......
	+35	−4	−27	+163	−74	+70	−317	−332	−360	+305	+449	+605	+217	−107	+618	+730	−9	−983	−155	+46	10	10

Group 1. Washington, Oregon, California.
Group 2. Idaho, Utah, Nevada, Arizona.
Group 3. Montana, Wyoming, Colorado, New Mexico.
Group 4. Minnesota, Iowa, Missouri, Wisconsin, Indiana, Illinois.
Group 5. North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas.

It is always a difficult matter to combine climatological data for large areas and to properly interpret the results and this is particularly true in the case of precipitation. This element is probably the most variable of all in point of horizontal distribution.

Precipitation, in common with some other meteorological elements is characterized by an unsymmetrical frequency distribution about the mean, there being a much larger number of dry years than wet years generally in all parts of the world.

The method of assembling the annual departures of the rainfall from the average used by Dr. Clements, while not without its limitations, can be properly used when qualitative results only are essential. When the number of rainfall stations in any district is small, as in the case of the years prior to the eighties, the results may be inaccurate.

The results shown in Table 1 are significant, whatever may be one's opinion as to the connection between sun-spots and rainfall. To those who may not be familiar with previous investigations on this subject, it will probably seem that there is little, if any, doubt but that a direct connection exists; to others, the results will not be conclusive. I have sought, therefore, to obtain and present additional information bearing upon the question in order that we may the better appraise the records at their true value. There is, of course, considerable contemporary evidence as to the existence of drought when rainfall records are wanting. Douglass has skillfully used biological evidence to carry the rainfall record back into the preobservational period.

The net result of Table 1 is that epochs of sun-spot maxima are as likely to be associated with wet as dry years, taking the 23 States as a single geographic unit. Some groups, however, differ from the whole area and from each other; for example, the Pacific Coast States show a tendency to be dry rather than wet and the Missouri Valley States show a rather decided tendency to the contrary. In this connection it is interesting to consider quantitative results for practically the same geographic area as are included in Table 1. In Table 2 are given the monthly and annual precipitation departures for the climatic districts as published in Table 1 of the MONTHLY WEATHER REVIEW for each of the years 1909–1921. This term of years contains the results for the five years 1915–1919 of Table 1 and the six years immediately preceding. It will be found that important results will flow from the study of years of sun-spot minima as well as maxima.

TABLE 2.—*Annual precipitation departures, by districts, 1909–1921.*

	Missouri Valley.	Northern Slope.	Middle Slope.	Southern Slope.	Southern Plateau.	Middle Plateau.	Northern Plateau.	North Pacific.	Middle Pacific.	South Pacific.	Total.	Average.
1909......	+5.5	+0.5	+1.7	−7.8	+0.1	+2.0	+0.6	−0.8	+6.6	+9.8	+18.2	+1.82
1910......	−5.0	−3.0	−7.7	−12.2	−2.9	−3.5	−1.8	−2.9	−10.9	−7.6	−57.6	−5.76
1911......	−3.6	−0.5	−2.9	−4.5	+2.7	+0.5	−2.8	+0.9	−2.2	+5.5	−6.9	−0.69
1912......	−4.1	−0.1	−0.2	+0.4	−0.6	−0.3	+2.3	−2.1	−6.3	−3.4	−14.4	−1.44
1913......	−3.5	+0.4	+0.5	+0.5	−1.2	−0.3	−0.9	−8.3	−5.6	−1.4	−19.8	−1.98
1914......	−0.4	−2.3	−3.9	+6.3	+1.1	−0.9	−2.0	−2.5	−1.9	+3.5	−3.0	−0.30
1915......	+7.7	+2.5	+7.1	+0.6	+0.9	−1.5	−0.2	−4.1	+2.4	+3.2	+18.6	+1.86
1916......	−5.8	+0.2	−3.9	−4.7	+1.0	+0.6	+0.7	−9.7	−1.8	+4.8	−18.6	−1.86
1917......	−6.0	−0.7	−7.7	−8.9	−3.3	−3.5	−1.5	−6.1	−9.8	−6.3	−53.8	−5.38
1918......	−1.9	+0.9	+2.8	−4.8	+0.4	−0.9	−3.0	−7.0	−5.3	+3.0	−15.8	−1.58
1919......	−2.2	−1.8	−3.8	+0.1	+1.2	−2.2	−2.3	−9.6	−6.3	−4.9	−31.8	−3.18
1920......	−1.6	+0.2	+0.3	+0.1	−1.0	−0.8	−0.3	−3.4	−5.2	−2.8	−14.5	−1.45
1921......	−0.1	−0.2	−0.3	−0 3	±0.0	−0.1	−0.1	+0.2	−0.6	+0.2	−1.3	−0.13

Comparing the figures of the two tables for the five-year period 1915–1919, it is seen that in the main they are in agreement. The year 1917—a year of maximum sunspots—was a year of deficient precipitation practically throughout the United States, but not especially in Arizona; 1916, however, which from Table 1 might be considered a year of nearly normal precipitation, is clearly a year of deficient rain by Table 2. When the entire United States is considered as in the matter of Table 2, some interesting results are disclosed. The year 1909, which in Table 2 is a year of above normal rain, comes out with a deficiency of 0.4 inch for the entire United States. Actual and smoothed precipitation departures for the United States as a single geographic unit from 1893 to 1920 appear in Table 3.

From Table 3 (see below) I have selected the years when precipitation on the average for the entire area was above, or very close to, normal. It is found that but 8 of the 40 years considered meet those requirements. The years and the average departures follow:

Years.	Average departures.	Years.	Average departures.
	Inches.		*Inches.*
1884..........................	+2.0	1905..........................	−0.1
1882..........................	+1.0	1915..........................	−0.1
1881..........................	+0.4	1912..........................	−0.2
1906..........................	+0.3	1909..........................	−0.4

On the other hand, the years of marked drouth in some part or parts of the United States were as follows:

Years.	Average departures.	Years.	Average departures.
	Inches.		*Inches.*
1910..........................	−6.6	1918..........................	−3.4
1917..........................	−6.1	1893..........................	−3.4
1887..........................	−4.1	1894..........................	−3.3
1895..........................	−4.0	1886..........................	−3.2
1904..........................	−4.0	1890..........................	−3.1

The outstanding feature of the above exhibit is the skewness of the distribution about the mean and the magnitude of the negative departures as compared with the positive. It seems to be a rule of precipitation the world over that departures below the mean are greater than departures above and this, I take it, is the explanation of the large number of years with negative departures in Table 3.

It is probably not generally recognized that there has been no period of rainfall so generally abundant as that of the early eighties since the Weather Bureau records began. If that maximum be taken as the starting point, the next maximum occurred about 22 years later, and the second maximum, that of 1915—if a departure of 0.1 inch below the normal can be called a maximum—about 33 years later, both numbers being multiples of the ordinary 11-year sun-spot cycle.

The intervals between severe drouth years, considering the drouth of 1886–87 as the point of origin, are 3, 6, 17, 23, and 30 years, respectively. One of these drouths, 1886–87, lasted two years, and another one three years, 1893–1895; in the above count I have considered the years from the end of the 1886–87 drouth until the *beginning* of the succeeding drouth as comprising the interval between.

The local as compared with the general distribution of precipitation.—In order to study the rainfall distribution for specific areas I have tabulated the rainfall

statistics of the State of Arizona beginning with the early seventies. At that time five rainfall stations were in operation, and while the geographic distribution is not as good as might be desired there is no alternative other than to use them as they stand. The average departure of the annual rainfall for the two groups of years 1869–1873 and 1881–1885 is shown in the statement below:

Mean.	1869	1870	1871	1872	1873	Mean.	1881	1882	1883	1884	1885	Mean.
Departures(inches)	−0.7	−3.3	−3.3	+1.9	−2.5	−1.6	+1.0	+0.3	−1.0	+5.9	−4.2	+0.4

From the above it is clear that for Arizona rainfall was deficient for the spot maxima of 1870, but with a year of more than the average, 1872 intercalated in a series of dry years. For the spot maxima of 1883.9 rainfall on the average of the five years was greater than the mean contrary to hypothesis; in this group of years there was a single year of deficient rainfall intercalated in a series of wet years.

Elsewhere in this paper it is remarked that the early eighties were years of abundant rainfall generally in the United States; Arizona seems to have been no exception to the rule.

I now pass to a consideration of the period when rainfall statistics for Arizona are more numerous than for the earlier years. The Weather Bureau publication, *Climatological Data* (Arizona), contains yearly values of the average precipitation computed from the whole number of records in the State. The published record begins with the year 1897 and is continuous to date. I have computed the State averages for 1893–1896, thus making available a continuous record for the 29 years 1893–1921. From these data I have computed the annual departure of the State average from the 29-year mean. The actual and the smoothed departures are presented in Table 3, to which have been added, for the sake of comparison, the actual and smoothed departures for the United States for the 41 years 1881–1921.

The smoothing has been accomplished by the formula $b = \frac{1}{4}(a + 2b + c)$, where b is the middle year in any consecutive series of three years.

TABLE 3.—*Rainfall departures, United States (as a unit) and Arizona.*

Years.	Departures—United States. Actual.	Departures—United States. Smoothed.	Departures—Arizona. Actual.	Departures—Arizona. Smoothed.
1881	+0.4	+0.4		
1882	+1.0	+0.2		
1883	−1.6	±0.0		
1884	+2.0	+0.4		
1885	−0.3	−0.4		
1886	−3.2	−2.7		
1887	−4.1	−3.2		
1888	−1.4	−2.1		
1889	−1.7	−2.0		
1890	−3.1	−2.4		
1891	−1.9	−1.3		
1892	−2.4	−2.5		
1893	−3.4	−3.1	−2.2	−2.2
1894	−3.3	−3.5	−2.2	−2.2
1895	−4.0	−3.2	−2.1	−1.6
1896	−1.6	−2.1	+0.1	−0.6
1897	−1.3	−1.6	−0.5	−0.4
1898	−2.2	−2.1	−0.7	−1.7
1899	−2.6	−2.2	−4.9	−3.9
1900	−1.3	−2.0	−5.0	−4.4

TABLE 3.—*Rainfall departures, United States (as a unit) and Arizona*—Continued.

Year.	Departures—United States. Actual.	Departures—United States. Smoothed.	Departures—Arizona. Actual.	Departures—Arizona. Smoothed.
1901	−2.8	−2.1	−2.7	−3.4
1902	−1.4	−2.0	−3.0	−3.4
1903	−2.4	−2.5	−3.5	−3.0
1904	−4.0	−2.6	−3.5	+0.7
1905	−0.1	−1.0	+13.3	+6.4
1906	+0.3	−0.4	+2.6	+4.9
1907	−2.2	−1.6	+1.3	+1.8
1908	−2.3	−1.8	+2.2	+1.2
1909	−0.4	−2.4	−0.7	−0.9
1910	−6.6	−3.8	−4.3	−1.9
1911	−1.8	−2.6	+2.0	−0.2
1912	−0.2	−1.1	−0.7	−0.2
1913	−2.3	−1.8	−1.3	±0.0
1914	−2.6	−1.9	+3.5	+1.9
1915	−0.1	−1.5	+2.2	+2.9
1916	−3.3	−3.2	+3.7	+2.3
1917	−6.1	−4.7	−0.5	+1.2
1918	−3.4	−3.4	+1.4	+2.0
1919	−0.9	−1.5	+5.8	+3.2
1920	−0.9	−0.9	−0.1	+1.8
1921	−0.2			

The smoothed departures in both cases have served to form the two rainfall departure curves of Figure 1 and the smoothed sun-spot numbers as published in this REVIEW (**30:** 176 and **48:** 460) serve to form the curve of sun-spot numbers which also appears on Figure 1.

The Arizona rainfall departure curve does not show agreement with the sun-spot curve in the manner set forth in the hypothesis put forward in Dr. Clements' article. There is, of course, some agreement of a general character, as has been pointed out on a former page, but not such specific agreement as might be expected did the phenomena stand in the relation of cause and effect. While Dr. Clements has not made that claim, many other writers have sought to explain variations in precipitation as being due to a chain of events beginning with variations in terrestrial temperature which might properly react upon evaporation and that in turn upon cloudiness and the precipitation of rain.

The points in favor of the hypothesis which can be drawn from Figure 1 are a minimum of rainfall at the epoch of maximum sun spots of 1894.1 and also, though in a less degree, in 1917.6. It also appears that the maximum of sun spots in 1870 was associated with a minimum of rainfall in Arizona. On the other hand, there are the following inconsistencies between the facts and the hypothesis (1) the chief maximum precipitation of the 29 years occurred in 1905, about one year before spot maximum of 1906.4; the chief minimum of precipitation occurred ln 1899–1900 and a prominent secondary minimum occurred in 1910, neither period being a time of maximum sun spots as required by the hypothesis.

SUMMARY.

The difficulty of combining rainfall statistics for large areas is discussed; it is also pointed out that investigations of the suggested relation between the occurrence of sun spots and terrestrial rainfall have been made in various parts of the world, and further that the net result of those investigations is inconclusive and in some cases conflicting.

The rainfall statistics for 23 States west of the Mississippi have been presented in slightly condensed form from that adopted by Dr. Clements and it is pointed out that for the 20 years considered a wet year is as likely as a dry one at times of spot maxima.

Rainfall statistics for Arizona and also for the United States as a single geographic unit are considered. These data may be interpreted as showing in some cases a relation such as is claimed; in other cases, however, there are large outstanding differences which have not been accounted for.

The diagrammatic method of presenting the data of Arizona and the United States for comparison with the sun-spot curve has been tried; the degree or success may be left to the reader. Generally the results reached by this method are more or less unsatisfactory. For the practical work of forecasting, this method can not be recommended.

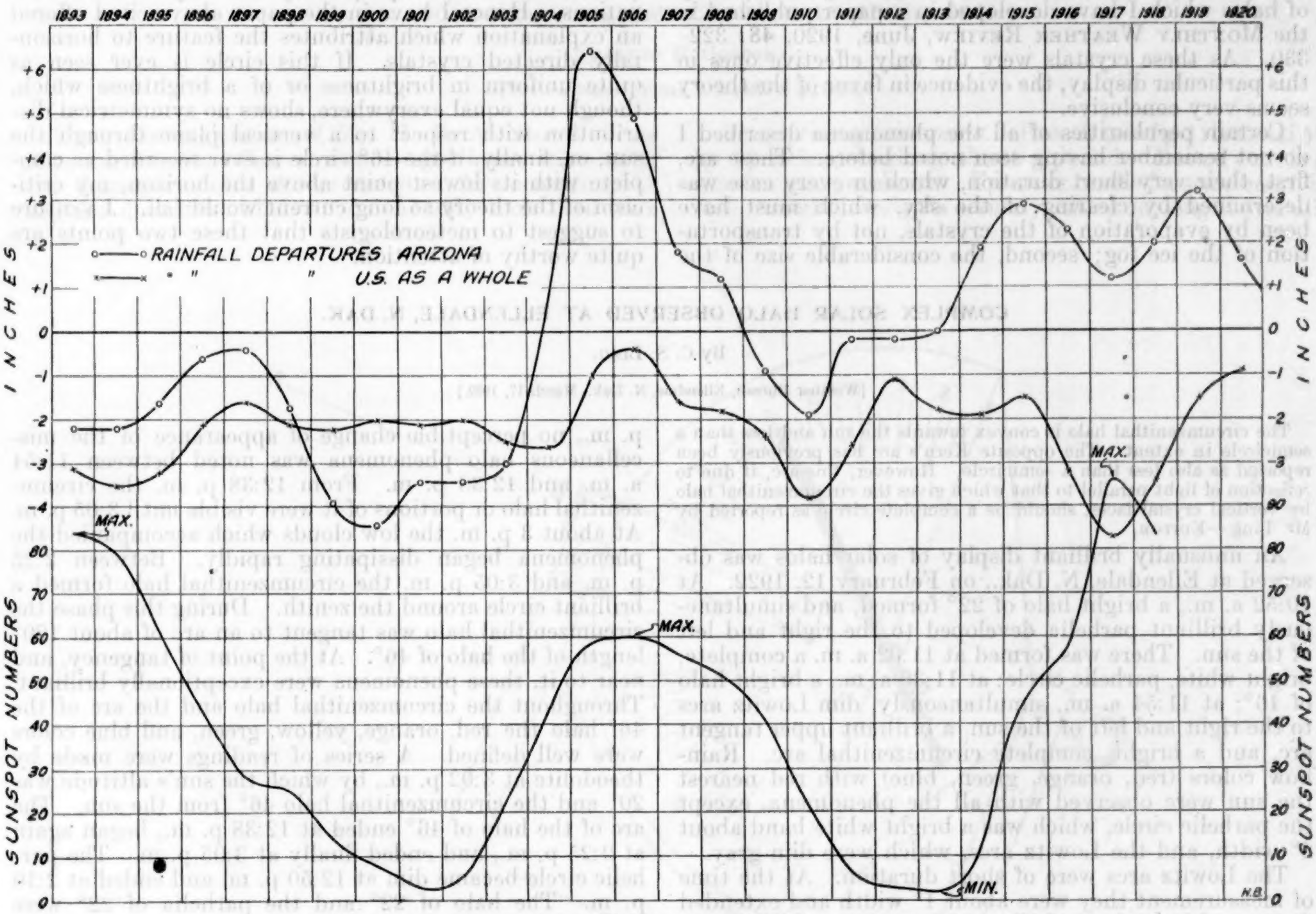

FIG. 1.—Rainfall abnormalities, Arizona and United States, and variation in sun-spot numbers, 1893-1920.

AN UNUSUAL HALO OBSERVED AT NEW HAVEN, CONN., FEBRUARY 25, 1922.

By CHARLES S. HASTINGS.

[Yale University, New Haven, Conn., Feb. 26, 1922.]

The halo was first seen by the writer at 10:10 a. m. At no time, either then or subsequently, was there a complete development. The feature which rendered it noteworthy was the effective presence of a single type of ice crystal. The common 22° circle was very faint, showing the approximate absence of fortuitously directed crystals, while the extreme faintness of the circumscribing oval, hardly more than suspected, demonstrated the almost total lack of elongated hexagonal crystals. On the other hand, the parhelion north of the sun was of a dazzling brightness, surpassing any which have previously been seen by me. The sky to the south of the sun was of a fine clearness, and therefore lacking in all indications of halo phenomena. Through the parhelion on the north was a well-defined portion of the parhelic circle, which extended through an azimuth angle of 20° to 30° beyond the parhelion to a portion of the sky free from haze. In the contrary direction it extended until lost in the light of the sun, being quite as bright where it crossed the 22° circle as at any other point.

Ten or fifteen minutes later the parhelion had become quite inconspicuous, with an added purity of the sky in its region, but of exceptionally pure spectral colors. At the same time upon a limited area of haze in the southwest appeared a well-marked portion of the parhelic circle and a paranthelion more distinct than any heretofore under my observation. The paranthelion was perfectly white, with no extension in any direction, and of a diame-

ter at least four or five times that of the sun. Both these features lasted only a few minutes, when the sky resumed an aspect of clearness.

All of these features could be produced by, and only by, thin hexagonal plates of ice with their crystalline axes steadily vertical, or, in other words, with the plates persistently horizontal. The paranthelion, the explanation of which has given so much trouble to theorists, is produced by successive total interior reflections from vertical faces inclined at 120°, according to a general theory of halos which I have developed in a paper published in the MONTHLY WEATHER REVIEW, June, 1920, **48**: 322–330. As these crystals were the only effective ones in this particular display, the evidence in favor of the theory seems very conclusive.

Certain peculiarities of all the phenomena described I do not remember having seen noted before. These are, first, their very short duration, which in every case was determined by clearing of the sky, which must have been by evaporation of the crystals, not by transportation of the ice fog; second, the considerable size of the paranthelion. These argue a very small size for the individual crystals. Perhaps only such can possess great stability of direction in the atmosphere.

There is one feature of halos of which the theory is still in an unsatisfactory state, and that is the often-seen 46° circle. According to the long-accepted theory, this is produced by right-angled refracting edges with wholly random directions, just as the 22° circle is produced by 60° prisms. This theory has seemed to me questionable, a doubt founded chiefly upon my own very limited observations. Hence I have in the paper above cited offered an explanation which attributes the feature to horizontally directed crystals. If this circle is ever seen as quite uniform in brightness or of a brightness which, though not equal everywhere, shows no symmetrical distribution with respect to a vertical plane through the sun, or, finally, if the 46° circle is ever recorded as complete with its lowest point above the horizon, my criticism of the theory so long current would fall. I venture to suggest to meteorologists that these two points are quite worthy of attention.

COMPLEX SOLAR HALO OBSERVED AT ELLENDALE, N. DAK.

By C. S. LING.

[Weather Bureau, Ellendale, N. Dak., March 17, 1922.]

The circumzenithal halo is convex towards the sun and less than a semicircle in extent. The opposite Kern's arc has previously been reported as also less than a semicircle. However, this arc, if due to reflection of light parallel to that which gives the circumzenithal halo by vertical crystal faces, should be a complete circle as reported by Mr. Ling.—EDITOR.

An unusually brilliant display of solar halos was observed at Ellendale, N. Dak., on February 12, 1922. At 10:52 a. m., a bright halo of 22° formed, and simultaneously brilliant parhelia developed to the right and left of the sun. There was formed at 11:02 a. m. a complete, bright white, parhelic circle; at 11:30 a. m., a bright halo of 46°; at 11:54 a. m., simultaneously, dim Lowitz arcs to the right and left of the sun, a brilliant upper tangent arc, and a bright, complete circumzenithal arc. Rainbow colors (red, orange, green, blue) with red nearest the sun were observed with all the phenomena, except the parhelic circle, which was a bright white band about 2° width, and the Lowitz arcs, which were dim gray.

The Lowitz arcs were of short duration. At the time of measurement they were about 1° width and extended downward from the parhelia of 22° on the parhelic circle, a distance of about 8° vertical angular measurement. Their direction of extension was apparently about parallel with the curvature of the halo of 22°.

When the circumzenithal halo was measured at 11:58 a. m. it was separated from the halo of 46° by about 4° to 5°. It formed a circle of about 10° radius around the zenith, was 50° from the sun, was bright throughout (not noticeably brighter on the side next the sun), and the red, orange, yellow, and blue colors were sharply defined. At this time the angular altitude of the sun was 30°. The measurements of the radius of the circumzenithal halo and its distance from the sun were difficult to obtain and no doubt as a result are slightly inaccurate. On account of the base plate of the theodolite, the phenomena having high angular altitudes could not be sighted, and it was necessary to obtain readings by observing the theodolite's field as it was passed by the colored bands of the halo of 46° and the circumzenithal halo. With the exception of the ending of the Lowitz arcs at 12:08 p. m., no perceptible change of appearance of the miscellaneous halo phenomena was noted between 11:54 a. m. and 12:38 p. m. From 12:38 p. m. the circumzenithal halo or portions of it were visible until 3:05 p. m. At about 3 p. m. the low clouds which accompanied the phenomena began dissipating rapidly. Between 2:25 p. m. and 3:05 p. m. the circumzenithal halo formed a brilliant circle around the zenith. During this phase the circumzenithal halo was tangent to an arc of about 120° length of the halo of 46°. At the point of tangency, and near to it, these phenomena were exceptionally brilliant. Throughout the circumzenithal halo and the arc of the 46° halo the red, orange, yellow, green, and blue colors were well defined. A series of readings were made by theodolite at 3:02 p. m., by which the sun's altitude was 20° and the circumzenithal halo 46° from the sun. The arc of the halo of 46° ended at 12:38 p. m., began again at 2:25 p. m., and ended finally at 3:05 p. m. The parhelic circle became dim at 12:50 p. m. and ended at 2:10 p. m. The halo of 22° and the parhelia of 22° were brilliant throughout the period of observation and ended simultaneously at 5:04 p. m.

The halos were preceded by light snow, beginning 9:02 a. m. and ending 10:24 a. m. High barometric pressure existed over eastern Montana and low pressure over Wyoming. Thin, slightly bunched clouds of stratus appearance prevailed. As the bunched clouds passed near the sun the phenomena brightened. The base of these clouds was about 400 meters' altitude. Ice crystals are believed to have existed underneath the clouds to within about 275 meters of the ground.

These conclusions relative to altitude of the clouds are based on observations of a pilot balloon. When about 275 meters above the ground the pilot balloon was very dim, and immediately after the second minute of observation (414 meters' altitude) abruptly entered the base of the clouds. The clouds formed as result of a small temperature inversion about 300 meters above the ground It is not thought they were the result of a diurnal temperature change. It is more likely they occurred along

the boundary between high and low pressure conditions, and that when the high pressure gained control over the weather conditions they dissipated. As indicated by the kite meteorogram record, this inversion was only about 0.5° C., and probably continued throughout the period of low clouds. While the clouds existed the wind velocities were about 50 per cent greater than before or afterward. Had the temperature gradient been greater at this inversion the clouds would have been denser and less favorable for halo formation. As low clouds in winter conditions are usually thick-layered, the complex halo phenomena that accompany the thinner type of low clouds are infrequent. When complex halo phenomena exist it seems that definite knowledge of the height of the clouds would be interesting. With summer conditions, low clouds consist of vapor particles and are not productive of halo formations.

AN ANGLE-MEASURING DEVICE FOR HALO OBSERVERS.

By JAMES H. GORDON.

[Weather Bureau, Yuma, Ariz., March 29, 1922.]

Upon the suggestion of Mr. H. F. Alciatore, of the Weather Bureau office at San Diego, I am submitting the description of a device designed for measuring the angular diameter of halos. As the only tools used were pocketknife, saw, hammer, plane, and a pair of dividers, the instrument could be made by anyone. It really has many uses. In addition to halo observing, it may be used as a crude sextant, accurate within a degree, for observing northern lights. It has enabled me to make clear points in regard to astronomy that were not otherwise well understood. Two observers a known distance apart could determine cloud heights with it and thus compute their velocity.

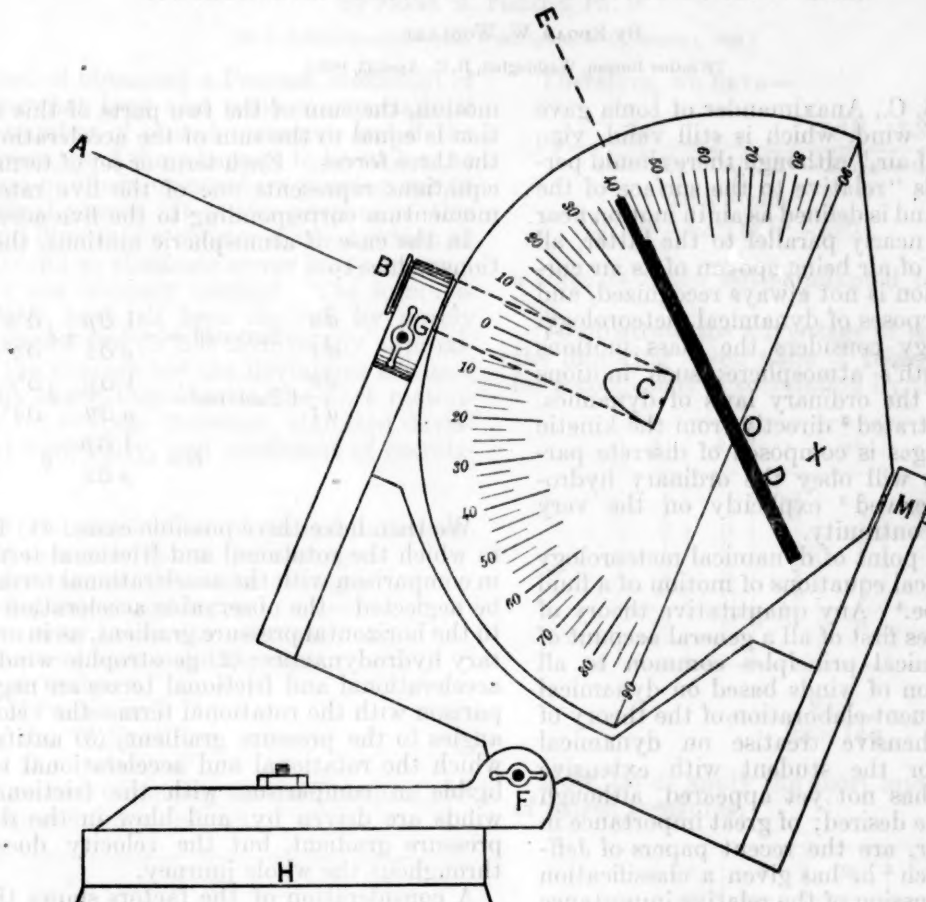

FIG. 1.—Device for measuring halos and other celestial phenomena.

Description of instrument.—Base *H* (see fig. 1) is metal 5½ by 5½ inches, weighing about a pound. Bolted to it is a wooden piece, as shown. Frame or cradle for scale board is inch material, uprights securely nailed on; length over all, 9½ inches; height of uprights to centers, 5½ inches. Scale board is inch material; diameter, 9¾ inches; length, 7¼ inches. Centering tube is set into the board 3¾ inches and extends about three-fourths inch beyond the board to form an axle for turning. Size of tube, 12-gage brass shell; aperture to admit ray of light is the caphole of the shell. On wood at back end of tube paper is pasted and a black spot marked on which the ray of light must center. Enough of the tube is cut away at the back end

to permit observation for centering ray of light. With lunar halos it is rarely possible to center by means of the ray of light. In this case the pointer is set at zero and centered on moon by adjustment at F. Set screw at F is clamped, and pointer moved to limb of halo as in the other case. Brass strap over tube holds it in place and may be tightened by set screw G to hold scale board in place. Axle at M is a pin used for a maximum thermometer with old-style thermometer support, flattened at end and driven into scale board, furnishing a handle for turning or holding the board. Pointer D is about one-third inch thick material and three-fourths inch wide—width to provide place for level. Nephoscope level has been used and works well. I have not yet arranged a satisfactory mounting for level to insure that scale board is in vertical plane when that is desired.

For halos.—By shifting of base H and angle of inclination at F, center ray of light from sun A passing through small aperture at B on point C at center of back of tube visible through cut out. If halo is complete no shifting of board X is necessary; if but a portion is visible, board may be turned on axis BM, so that the pointer D will bear on the segment visible. Sight along pointer D turning on pivot O until it bears on the limb of the halo. Angle of radius of halo will be shown by pointer on scale.

Angular elevation of any heavenly body.—Set pointer D at zero; set small level on pointer D; turn at F as necessary to level pointer. Clamp F.—This establishes horizon. Turn pointer on object whose elevation is desired and position of pointer on scale will show angle.

Angles in horizontal plane may be measured by leveling board X and clamping at F and G to hold stationary. If desired, C on the scale may be set true north or south by means of compass. Sighting along pointer D at objects whose angular relation is desired and noting reading on scale in each case gives data desired.

RECENT CONTRIBUTIONS TO DYNAMICAL METEOROLOGY.

By EDGAR W. WOOLARD.

[Weather Bureau, Washington, D. C., April 13, 1922.]

In the fifth century B. C., Anaximander of Ionia gave a scientific definition of wind, which is still valid, viz., "The wind is a flowing of air," although there should perhaps be added the words "relative to the surface of the earth." Sometimes a wind is defined as air in motion near the earth's surface and nearly parallel to the latter, all other motions of masses of air being spoken of as air currents; [1] but this distinction is not always recognized, and it is unimportant for purposes of dynamical meteorology.

Dynamical meteorology considers the mass motions taking place in the earth's atmosphere; such motions must of necessity obey the ordinary laws of dynamics. Now, it may be demonstrated [2] directly from the kinetic theory that although a gas is composed of discrete particles, its mass motions will obey the ordinary hydrodynamical equations derived [3] explicitly on the very different assumption of continuity.

Therefore the starting point of dynamical meteorology will be the hydrodynamical equations of motion of a fluid covering a rotating globe.[4] Any quantitative theory of the various winds involves first of all a general account of the fundamental dynamical principles common to all winds, and a classification of winds based on dynamical principles, with a subsequent elaboration of the theory of each type. A comprehensive treatise on dynamical meteorology, written for the student with extensive mathematical training, has not yet appeared, although such a work is much to be desired; of great importance in this connection, however, are the recent papers of Jeffreys, in the latest of which [5] he has given a classification of winds, based on a discussion of the relative importance of the various relevant physical factors which determine the characteristics of each type as expressed in the differential equations of motion.

The only forces acting on any mass of air are gravity, hydrostatic pressure, and friction; the acceleration of the mass is composed of two parts—acceleration relative to the surface of the earth, which we observe, and the acceleration common to this surface itself; by the laws of motion, the sum of the two parts of this actual acceleration is equal to the sum of the accelerations produced by the three forces. Each term or set of terms in the general equations represents one of the five rates of change of momentum corresponding to the five accelerations.

In the case of atmospheric motions, the general equations reduce to—

$$\left.\begin{aligned} \frac{du}{dt} - 2\omega v\cos\theta &= -\frac{1}{\rho}\frac{\partial p}{\partial x} + k\frac{\partial^2 u}{\partial z^2} \\ \frac{dv}{dt} + 2\omega u\cos\theta &= -\frac{1}{\rho}\frac{\partial p}{\partial y} + k\frac{\partial^2 v}{\partial z^2} \\ 0 &= -\frac{1}{\rho}\frac{\partial p}{\partial z} - g \end{aligned}\right\}$$

We then have three possible cases: (1) Eulerian winds, in which the rotational and frictional terms are so small in comparison with the accelerational term that they may be neglected—the observable acceleration corresponds to to the horizontal pressure gradient, as in ordinary elementary hydrodynamics; (2) geostrophic winds, in which the accelerational and frictional terms are negligible in comparison with the rotational term—the velocity is at right angles to the pressure gradient; (3) antitriptic winds, in which the rotational and accelerational terms are negligible in comparison with the frictional term—these winds are driven by, and blow in the direction of the pressure gradient, but the velocity does not increase throughout the whole journey.

A consideration of the factors shows that winds on a scale comparable with the size of the British Isles, or larger, are geostrophic; tropical cyclones, and all cyclostrophic winds, as tornadoes, are Eulerian; land and sea breezes, and mountain and valley winds, are mainly antitriptic. However, in order to explain seasonal pressure changes at the earth's surface, the accelerational term must be retained in the equations for the geostrophic wind; temperature differences are capable of accounting for the annual pressure variation in Asia and probably for the permanent winds of Antarctica. Jeffreys has worked out a mathematical theory of some of the antitriptic winds which agrees well with the facts. A fundamental part is played by the deviation of the actual average temperature lapse rate from the adiabatic value.

[1] *Cf.* W. I. Milham, *Meteorology*, New York, 1912, p. 136; W. M. Davis, *Elementary Meteorology*, 1894, p. 93.

[2] J. H. Jeans, *The Dynamical Theory of Gases*, 3 ed., Cambridge, 1921, pp. 165–175.

[3] See P. Appell, *Traité de Mécanique Rationnelle*, Tome 3, 3 ed., Paris, 1921; H. Lamb, *Hydrodynamics*, 4 ed., Cambridge Press, 1916.

[4] Lamb, *op. cit.*, p. 318.

[5] Harold Jeffreys, On the Dynamics of Wind. *Quar. Jour. Roy. Met'l Soc.*, 48 : 29–47, 1922.

Classical hydrodynamics, however, does not afford a satisfactory means of dealing with the general equations of motion derived above, for they involve the density, and wherever, as a consequence, it is necessary to take into account the physical properties of the fluid, the classical theory practically always assumes an equation of state of the form $f(p, \rho)=0$, the density being a function of the pressure only.[6] In the actual cases of nature, particularly in meteorology and hydrography, many other independent variables enter, such as temperature, humidity, salinity, etc. The hydrodynamical theory of *baroclinic* fluids—i. e., fluids in which other independent variables than the pressure also affect the density—has been worked out by Bjerknes and has recently been made easily accessible in elementary form by Appell.[7] In such fluids surfaces of equal density are not always surfaces of equal pressure, and the formation and annihilation of vortices are possible.

The application of this theory to the dynamics of the earth's atmosphere has also been largely the work of Bjerknes, having been worked out in parallel with the well-known empirical investigations of the Bergen meteorologists. There has recently appeared a comprehensive and up-to-date summary of the whole subject,[8] which constitutes a most valuable memoir on theoretical meteorology.

[6] See Lamb, *op. cit.*, art. 8; *cf.* Appell, *op. cit.*, art. 627.

[7] Appell, *op. cit.*, chap. xxxii, pp. 562-605.

[8] V. Bjerknes, On the Dynamics of the Circular Vortex, with applications to the Atmosphere and Atmospheric Vortex and Wave Motions. *Geofysiske Publikationer*, Vol. II, No. 4, Kristiania, 1921. 4to, 88 pp.

SHORT METHOD OF OBTAINING A PEARSON COEFFICIENT OF CORRELATION, AND OTHER SHORT STATISTICAL PROCESSES.

By FRANK M. PHILLIPS, Ph. D.

[U. S. Public Health Service, Washington, D. C., March 1, 1922.]

The usual method of obtaining a Pearson coefficient of correlation is somewhat long and tedious, especially if there be a large number of paired measures and if the measures or the averages of these happen to be such as to involve either large numbers or numbers running out to two or three decimal places. It is the purpose of this paper to derive and illustrate a shorter method, which at the same time will tend to eliminate errors likely to creep into a solution by the ordinary method. The formulas given in this article have all been derived by purely mathematical processes and do not involve any approximations; neither the average nor the deviations are used in computations by them; they shorten the work materially when solving for average deviation, standard deviation, coefficient of variability, and coefficient of correlation.

Let—

n = number of independent, or of paired, measures.
n_- = number of measures below the average.
n_+ = number of measures above the average.
Σm = sum of independent measures.
Σm_- = sum of measures below the average.
Σm_+ = sum of measures above the average.
S = measures of "subject."
R = measures of "relative."
a = average of the "subject."
c = average of the "relative."

Then the usual process of getting the coefficient of correlation may be represented as follows:

S	R	x	y	x^2	y^2	xy
S_1...	R_1..	S_1-a.	R_1-c..	$S_1^2-2S_1a+a^2$....	$R_1^2-2R_1c+c^2$....	$S_1R_1-S_1c-R_1a+ac$.
S_2...	R_2..	S_2-a	R_2-c..	$S_2^2-2S_2a+a^2$....	$R_2^2-2R_2c+c_2$....	$S_2R_2-S_2c-R_2a+ac$.
S_3...	R_3..	S_3-a	R_3-c..	$S_3^3-2S_3a+a^2$....	$R_3^2-2R_3c+c^2$....	$S_3R_3-S_3c-R_3a+ac$.
....	....	......	......	....	....	....
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....	....	......	......	....	....	....
S_n..	R_n.	S_n-a	R_n-c..	$S_n^2-2S_na+a^2$ ...	$R_n^2-2R_nc+c^2$...	$S_nR_n-S_nc-R_na+ac$.
ΣS..	ΣR	....	....	$\Sigma S^2-2\Sigma Sa+na^2$..	$\Sigma R^2-2\Sigma Rc+nc^2$.	$\Sigma SR-\Sigma Sc-\Sigma Ra+nac$.

$$r=\frac{\Sigma xy}{n\sigma_S\sigma_R}=\frac{\Sigma xy}{\sqrt{\Sigma x^2\cdot\Sigma y^2}}$$

Now, since $\Sigma S=na$, and $\Sigma R=nc$, then $\Sigma Sc=nac$, $\Sigma Ra=nac$, and $\Sigma SR-\Sigma Sc-\Sigma Ra+nac=\Sigma SR-nac$; furthermore, since $\Sigma Sa=na^2$, and $\Sigma Rc=nc^2$, then $\Sigma S^2-2\Sigma Sa+na^2=\Sigma S^2-na^2$, and $\Sigma R^2-2\Sigma Rc+nc^2=\Sigma R^2-nc^2$.

Therefore, we have—

$$r=\frac{\Sigma xy}{\sqrt{\Sigma x^2\cdot\Sigma y^2}}=\frac{\Sigma SR-\Sigma Sc-\Sigma Ra+nac}{\sqrt{(\Sigma S^2-2\Sigma Sa+na^2)\ (\Sigma R^2-2\Sigma Rc+nc^2)}}$$

$$=\frac{\Sigma SR-nac}{\sqrt{(\Sigma S^2-na^2)\,(\Sigma R^2\ nc^2)}}$$

a formula much better adapted to numerical computation.

To illustrate the advantage of this method, let us take the following seven pairs of related measures and solve for a coefficient of correlation by the usual method:

S	R	x	x^2	y	y^2	xy
4	5	−3	9	−7	49	21
5	8	−2	4	−4	16	8
6	11	−1	1	−1	1	1
7	11	0	0	−1	1	0
8	13	1	1	1	1	1
9	18	2	4	6	36	12
10	18	3	9	6	36	18
49 $a=7$	84 $c=12$	....	28	....	140	61

$$r=\frac{61}{28\times 140}=0.974.$$

Now, let us apply the short method to the same series of paired measures:

S	R	S^2	R^2	SR
4	5	16	25	20
5	8	25	64	40
6	11	36	121	66
7	11	49	121	77
8	13	64	169	104
9	18	81	324	162
10	18	100	324	180
49	84	371 343	1,148 1,008	649 588
$a=7$	$c=12$	28	140	61

$nac=588.$
$na^2=343.$
$nc^1=1,008.$

$$r=\frac{61}{\sqrt{28\times 140}}=0.974.$$

It will be observed that the two methods give identical results. By using the new method it is necessary only to use a table of squares and an adding machine, if these are available, and about one-tenth of the time ordinarily used for finding the coefficient of correlation.

If it is desired to get the standard deviations of these series, they are readily obtainable, because the quantities in the denominator are the sums of the squares of the deviations of these measures from their respective averages. We have the following additional formulae:

$$b_1 = r\frac{\sigma_S}{\sigma_R} = \left[\frac{\Sigma SR - nac}{\sqrt{(\Sigma S^2 - na^2)(\Sigma R^2 - nc^2)}}\right]\left[\frac{\sqrt{\frac{\Sigma S^2 - na^2}{n}}}{\sqrt{\frac{\Sigma R^2 - nc^2}{n}}}\right]$$

$$= \frac{\Sigma SR - nac}{\Sigma R^2 - nc^2}$$

$$b_2 = r\frac{\sigma_R}{\sigma_S} = \frac{\Sigma SR - nac}{\Sigma S^2 - na^2}$$

These values in the case of the above illustrative example are 2.18 and 0.436, respectively.

For single series of independent measures, we obviously have:

$$\text{Standard deviation} = \sqrt{\frac{\Sigma m^2 - na^2}{n}},$$

$$\text{Average deviation} = \frac{n(\Sigma m_+ - \Sigma m_-) - \Sigma m(n_+ - n_-)}{n^2},$$

$$\text{Coefficient of variation} = \sqrt{\frac{n\Sigma m^2 - (\Sigma m)^2}{\Sigma m}}.$$

Where possible the solution should be in terms of class intervals rather than in that of the unit of measure.

CLIMATE AND PHOTOGRAPHY.

By H. G. CORNTHWAITE.

[Rockville, Ind., April 16, 1922.]

SYNOPSIS.

The weather or climatic element in photography is an important one, first, because of the wide variations in the strength of daylight with the time of day, season of the year, condition of the sky, with latitude, and with altitude; and, second, because of the important effects of temperature and humidity conditions have on photographic chemical processes.

Camera operators often produce inferior work in an unfamiliar climatic environment, which suggests the desirability of becoming familiar with climatic and weather conditions and their effects upon photographic work and processes.

As with many other forms of human activity, the weather or climatic element is of first importance in photographic work.

The following notes and observations are based on the writer's experience operating a camera under varying climatic conditions.

The more important climatic influences affecting photographic work may be discussed under two heads: *Intensity of sunlight*, and *Weather conditions affecting photographic chemical processes*.

INTENSITY OF SUNLIGHT.

The intensity of sunlight is perhaps the most important climatic condition affecting outdoor speed photography, as it controls the time of exposure. It varies greatly with the season of the year, the time of day, the condition of the sky (cloudiness), with latitude, and to a less degree with altitude.

The diurnal variations in the actinic (photographic) strength of daylight is well known, the light being brightest when the sun is at or near the zenith and dimming rapidly with increasing obliquity of its rays.

The seasonal variation in the strength of daylight is due to the same cause, variations from season to season in the obliquity of the sun's rays. Amateur photographers too often overlook or underestimate the effects of this seasonal variation. A bright late autumn or winter day *looks* about as bright as a similar summer day, but the photographic strength of the light is perhaps twice as great in summer as in late autumn or winter.

Of a similar character are the variations in the photographic strength of daylight due to changes in latitude, the light being strongest in the Tropics and progressively dimming poleward in each direction. Here, too, photographers often fail to make proper allowance for the wide variations in the strength of light due to the varying degree of obliquity of the sun's rays in different latitudes.

Generally speaking, the photographic strength of light increases with altitude, as the air is less dense at higher altitudes and absorbs fewer of the sun's rays, especially the short wave-length rays of greatest photographic strength. At higher altitudes there is also a greater amount of reflected light gathered by the camera lens.

The effects of cloudiness and fog in reducing the strength of daylight are too well known to require comment.

The amount and distribution of rainfall *indirectly* affect the time required for outdoor exposures, especially landscapes, as rainfall controls in large measure the growth, distribution, and density of vegetation, and the light reflected from green vegetation is of weak photographic strength. Desert scenes require much shorter exposures than views in grassy or forest areas.

Heavy rainfall has a surprising effect on photographic exposures. During a heavy tropical downpour an exposure of one-twenty-fifth second with open lens (speed F. 8) was found to be correct, *the light being actually stronger photographically during the heavy downpour than it was in densely cloudy weather without rainfall*, due to the light reflected from the falling raindrops.

Tropical daylight is perhaps twice as strong photographically as summer daylight in latitude 40 and about four times as bright as winter daylight at this latitude. This relationship, of course, does not hold true when winter landscapes are covered with a dazzlingly white blanket of snow.

The light generally is brighter in the Rocky Mountain and Pacific coast sections of the United States than in the Central and Atlantic coast sections. It is much brighter also along the seacoast than inland.

WEATHER CONDITIONS AFFECTING PHOTOGRAPHIC CHEMICAL PROCESSES.

Temperature and humidity are the important weather elements affecting photographic chemical processes. Chemical activity in developing and fixing processes is

greatly increased with high temperatures and correspondingly retarded with low temperatures. Photographic films, negatives, and prints deteriorate rapidly under certain climatic conditions, and are preserved indefinitely under other favorable conditions.

Man can endure a high degree of humidity or a high temperature without distress, but there seems to be a *combination* of the two that is peculiarly inimical to human comfort and well-being. The same is true of photographic films and prints, which may be subjected either to high temperatures or high humidity without excessive deterioration, *but not to both in combination.*

Both prints and films deteriorate rapidly in the moist Tropics, due to the combined effects of high temperatures and high humidity. The writer has known an undeveloped exposed film to be ruined from mildew *in five days' time in the Tropics*, whereas in the Temperate Zone an exposed film was carried in the writer's camera for five months in the West (Oregon), six months in the East (New York), and six months in the Ohio Valley before being developed. *Even then it was only slightly damaged from mildew.*

Photographic prints, too, lose their permanence in the Tropics. Rarely will good professional prints withstand two years' exposure to moist tropical conditions without serious damage. It is therefore unsafe to take valuable photographic prints to the Tropics and allow them to remain for any considerable time. However, prints *developed and fixed* under tropical conditions have a much greater permanence in the Tropics than prints developed and printed in the Temperate Zone and subsequently taken to the Tropics.

CONCLUSION.

From what precedes it will be seen that climatic conditions powerfully influence photographic work. The writer has observed much photographic work spoiled or improperly done because the operator was working out of his accustomed climatic environment. A successful camera man should have at least a fair knowledge of climatology and meteorology. In concluding, suitable advice to photographers would be "Know your camera, lens, and shutter, and know also the climatic conditions under which it operates."

ANOMALOUS STORM TRACKS.

By EDWARD H. BOWIE, Meteorologist.

[Weather Bureau, Washington, D. C., April 1, 1922.]

There are to be found in the meteorological textbooks statements to the effect that cyclones are carried along in the general air currents that are assumed to prevail over the region occupied by the cyclone on any particular date; that these general air currents are subject to seasonal changes; and that the tracks of cyclones are subjected to corresponding changes in both the speed and direction of progression. It is in the main true that in the Tropics the cyclones on the first branches of their tracks move west or northwest and that extratropical cyclones move toward the east or northeast. But if individual cyclone tracks are considered, it will be found that the general rule is very often departed from; that cyclones of the extratropical regions often follow very irregular courses; and that marked variations in the speed of progression are not uncommon. Also, that the tracks of tropical cyclones are not symmetrical and like unto parabolas, as stated in the textbooks. It would simplify the work of the forecasters if cyclones, both tropical and extratropical, would behave in an orderly manner, but unfortunately they do not.

Why, after a cyclone has formed and started on its course, it does not pursue an even and orderly course from its birth to its disappearance is a matter not yet solved, but it must be inferred that in some cases, at least, fundamental changes in environment are encountered which cause these perturbations.

Figure 1 shows the path of five exceptionally erratic cyclones. One of these, that of April, 1903, had its origin over the Carolinas and described a loop over the vicinity of Chesapeake Bay; another, that of April, 1910, formed over Arkansas, moved northward to Wisconsin, where it described a loop and finally disappeared over Lake Erie; and another of the same month and year originated over Kansas, moved east-northeastward to the vicinity of Lake Michigan, where it described a loop and then moved southward and finally disappeared over Georgia; another, that of June, 1916, formed over New Mexico, followed what may be regarded as a normal course until it reached the vicinity of Lake Michigan, where it described a loop in its track and after doing so moved eastward in an orderly manner and finally disappeared off the north Atlantic coast. These storms were all of extratropical origin, but in all instances were well defined, and there is little or no doubt as to the accuracy of the charted positions of their centers. There is also indicated on this chart the track of a West Indian hurricane of October, 1910. It formed over the Caribbean Sea, moved north-northwestward, crossed the western end of Cuba, and in that region the center described a loop and after doing so passed north-northeastward in a normal course. As there had been considerable doubt as to the track this hurricane actually followed, it was recently made the subject of a special study, all available data from land observatories and vessels in that region being used in preparing the daily synoptic charts, by the Observatorio Nacional, Casa Blanca, Habana, Cuba, and later by the Weather Bureau, Washington, D. C. The independent studies were in agreement and to the effect that the track followed was essentially that shown on the chart.

The study at Habana of the hurricane of October, 1910, was made by Dr. José Carlo Millás, Director, Observatorio Nacional, assisted by Dr. Carlos Theye, Mr. Manuel Maria Garcia Blanco, and Mr. Miguel Gutierrez. Dr. Millás, in a recent letter to the Chief of the Weather Bureau concerning this study, wrote as follows:

> The following hypotheses have been studied in the effort to explain the bad weather during five days of October, 1910, in the western part of Cuba:
>
> 1. Elliptical form of cyclone.
> 2. Inclination of the axis.
> 3. Loop.
> 4. Bell-shaped parabola.
> 5. Point d'arrêt.
> 6. Two cyclones.
>
> 1. The elliptical form of cycloae, the inclination of the axis, the bell-shaped parabola, and the point d'arrêt can not explain the observed phenomena.
>
> 2. The hypothesis of two cyclones has been also rejected for the following reasons:
>
> (*a*) Due to theoretical reasons, two hurricanes of considerable intensity can not coexist in such close proximity.

(*b*) Because vessels in the Gulf of Mexico and the northwest Caribbean Sea for the days in question always showed winds inclined toward a single center.

(*c*) Because the barometers of these vessels and all those in the western part of Cuba during the 14th, 15th, and 16th; the direction and violence of the winds; the direction of the low clouds; everything pointed to the fact that the hurricane center that had passed a short distance to the west of Pinar del Rio had not traveled far, and never could it be admitted that it had disappeared.

(*d*) All the winds in the western part of Cuba, after the night of the 13th, correspond, according to known laws, to the lower part of a hurricane.

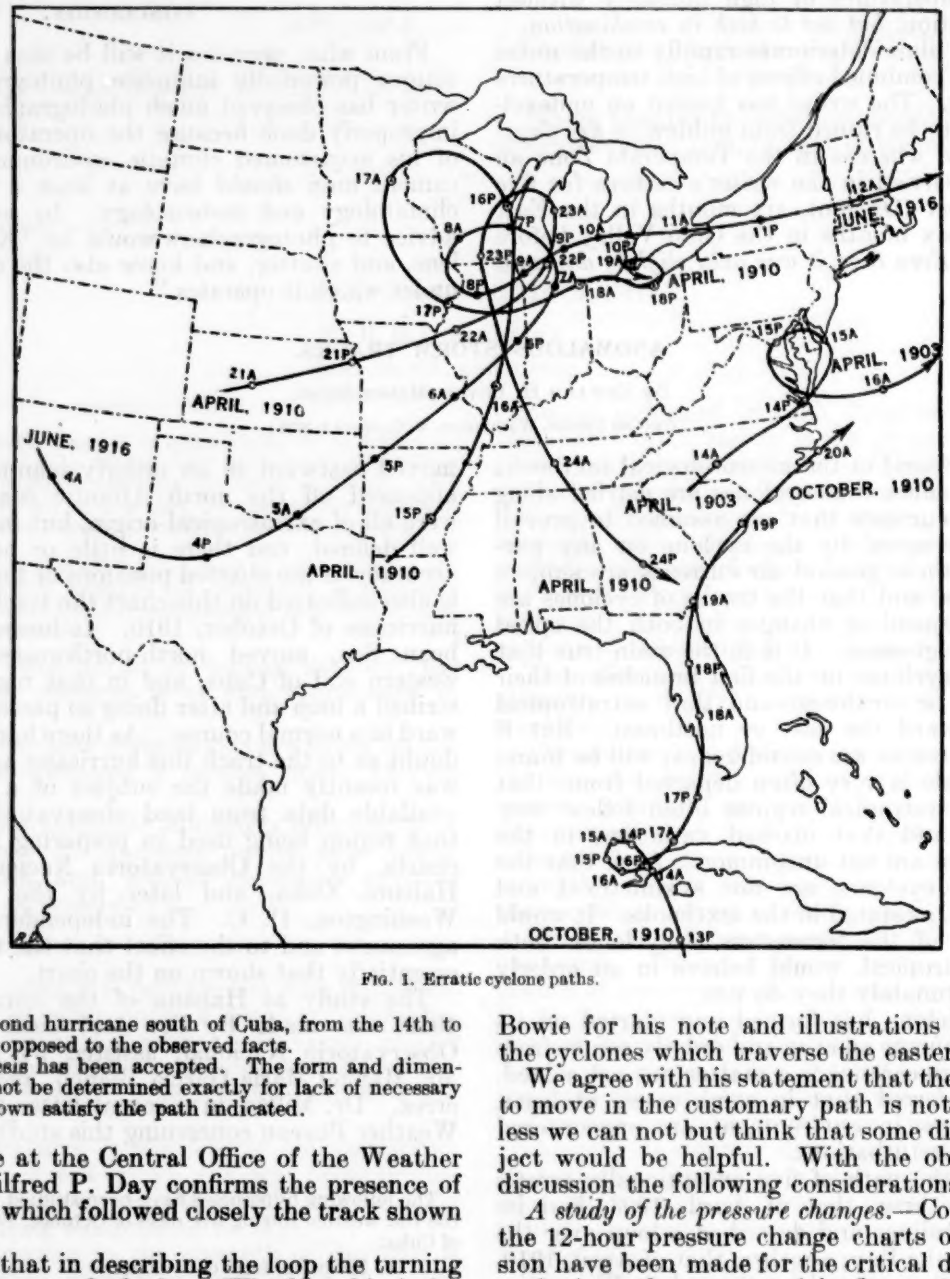

FIG. 1. Erratic cyclone paths.

3. The path of a second hurricane south of Cuba, from the 14th to the 16th of October, is opposed to the observed facts.

4. The loop hypothesis has been accepted. The form and dimensions of the loop can not be determined exactly for lack of necessary observations; those known satisfy the path indicated.

The study made at the Central Office of the Weather Bureau by Mr. Wilfred P. Day confirms the presence of but one hurricane, which followed closely the track shown on figure 1.

It will be noted that in describing the loop the turning in all cases was counterclockwise. Whether this is invariable is not known.

These paths are presented as interesting and curious departures from normal cyclone tracks. The explanation is not obvious.

DISCUSSION.

By A. J. Henry.

The failure of cyclonic areas to move in the path predetermined for them by the forecaster, has wrecked many otherwise perfectly good forecasts. Naturally much attention has been devoted to the weather maps which provide good examples of failures to move in the ordinary path, and we are indebted to Supervising Forecaster Bowie for his note and illustrations of erratic paths in the cyclones which traverse the eastern United States.

We agree with his statement that the cause of the failure to move in the customary path is not obvious, nevertheless we can not but think that some discussion of the subject would be helpful. With the object of stimulating discussion the following considerations are offered:

A study of the pressure changes.—Copies of a number of the 12-hour pressure change charts of the forecast division have been made for the critical dates in most of the cyclonic paths presented in figure 1. Before entering upon a discussion of these charts it is necessary to describe in some detail the method of making them, and therefore the writer's apologies are offered for repeating what many readers may be familiar with.

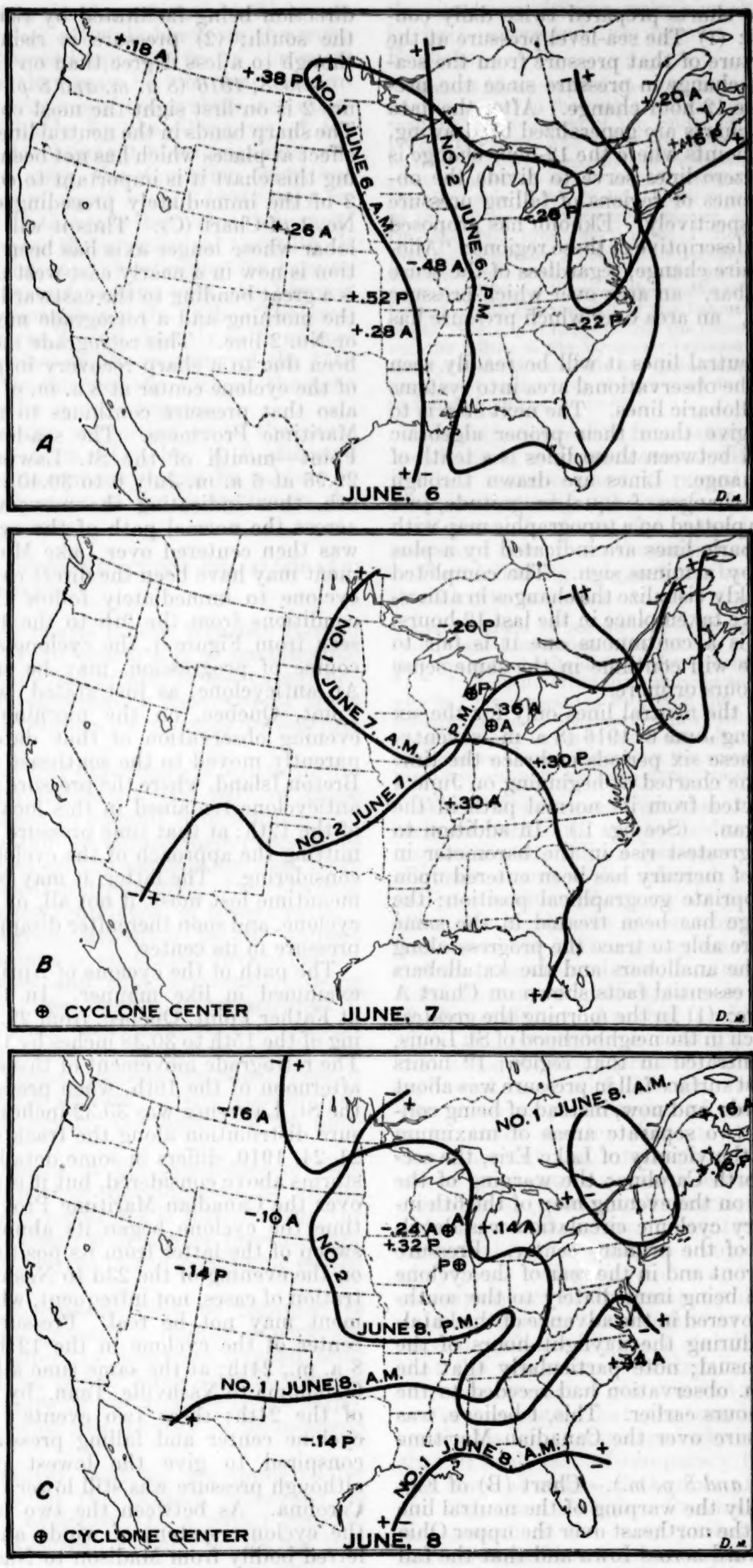

FIG. 2. Neutral lines of pressure change on dates of erratic cyclonic movement.

The pressure change charts prepared twice daily contain the following data: (1) The sea-level pressure at the station; (2) the departure of that pressure from the seasonal average; (3) the change in pressure since the preceding observation—the 12-hour change. After the data have been entered the charts are generalized by drawing, first, lines through the points where the 12-hour change is zero; these neutral or zero lines serve to divide the observational area into zones or regions of falling pressure and rising pressure, respectively. Ekholm has proposed the following names as descriptive of these regions: "Allobar," any area or pressure change, regardless of the sense of the change; "Anallobar," an area over which pressure has risen; "Katallobar," an area over which pressure has fallen.

After drawing the neutral lines it will be readily seen that these lines divide the observational area into systems of anallobaric and katallobaric lines. The next step is to draw these lines and give them their proper algebraic sign; the usual interval between these lines is a tenth of an inch of pressure change. Lines are drawn through points having pressure changes of equal magnitude, just as contour intervals are plotted on a topographic map with this difference—anallobaric lines are indicated by a plus sign and katallobaric by a minus sign. The completed map enables one to quickly visualize the changes in atmospheric pressure that have taken place in the last 12 hours, and since the process is a continuous one it is fair to assume that the change will continue in the same sense during the coming 36 hours or more.

In figure 2 are given the neutral lines only for the six 12-hour periods beginning June 6, 1916 (8 a. m., seventy-fifth meridian time); these six periods embrace the time during which the cyclone charted as beginning on June 4 of that year was deflected from its normal path in the vicinity of Lake Michigan. (See fig. 1.) In addition to the neutral lines, the greatest rise in the barometer in hundredths of an inch of mercury has been entered upon the charts in its appropriate geographical position; the greatest negative change has been treated in the same manner; and thus we are able to trace the progress along the earth's surface of the anallobars and the katallobars from day to day. The essential facts shown on Chart A of figure 2, for June 6 are: (1) In the morning the greatest pressure fall was 0.48 inch in the neighborhood of St. Louis, Mo., and it was concentrated in that region; 12 hours later the place of greatest surface fall in pressure was about 500 miles to the eastward; and now, instead of being concentrated in one spot, two separate areas of maximum fall appear, the first in the vicinity of Lake Erie, the second in northeastern North Carolina; the warping of the isobars over that region on the evening map of the 6th indicated that a secondary cyclonic circulation was developing to the southeast of the primary center. Pressure was rising both in the front and in the rear of the cyclone center, the greatest rise being immediately to the southwest; (2) the distance covered in the advance of the katallobar to the eastward during the daylight hours of the 6th was smaller than usual; note particularly that the neutral line at the p. m. observation had receded to the west of its position 12 hours earlier. This, I believe, was due to the rising pressure over the Canadian Maritime Provinces.

June 7, 1916 (8 a. m. and 8 p. m.).—Chart (B) of Figure 2: (1) Note especially the warping of the neutral line of the morning chart to the northeast over the upper Ohio valley and to the westward across Iowa and that the fall in pressure at the surface has apparently moved north-northwest across Lake Superior, its movement in that direction being facilitated by rising pressure directly to the south; (2) pressure is rising over New England, though to a less degree than on the previous day.

June 8, 1916 (8 a. m. and 8 p. m.).—Chart (C) of Figure 2 is on first sight the most complicated of the series. The sharp bends in the neutral lines suggest a local surface effect at places which has not been eliminated. In studying this chart it is important to compare neutral line No. 2 of the immediately preceding chart with neutral line No. 1 of Chart (C). Thus it will be seen that the katallobar whose longer axis has been in a north-south direction is now in a nearly east-west direction and that there is a great bending to the eastward of neutral line No. 1 in the morning and a retrograde movement in the evening or No. 2 line. This retrograde movement seems to have been due to a sharp recovery in pressure in the vicinity of the cyclone center at 8 a. m. of the 8th of July. Note also that pressure continues to rise over the Canadian Maritime Provinces. The sea-level pressure at Father Point—mouth of the St. Lawrence River—rose from 29.96 at 6 a. m. July 6 to 30.40 inches at 8 a. m. of the 9th, thus indicating the movement of an anticyclone across the normal path of the cyclone of July 7, which was then centered over Lake Michigan, and this movement may have been the direct cause of the failure of the cyclone to immediately follow the normal path. The conditions from the 9th to the 10th, when, as may be seen from Figure 1, the cyclone again took up a normal course of progression, may be summarized as follows: An anticyclone, as just stated, was centered at Father Point, Quebec, on the morning of the 9th. At the evening observation of that date the center had apparently moved to the southeast as far as Sydney, Cape Breton Island, where the pressure was 30.48 inches. The anticyclone remained in this location until the morning of the 12th; at that time pressure began to fall, thus permitting the approach of the cyclone which we have been considering. The latter, it may be remarked, had in the meantime lost most, if not all, of the characteristics of a cyclone, and soon thereafter disappeared because of rising pressure in its center.

The path of the cyclone of April 15–18, 1910, has been examined in like manner. In this case pressure rose at Father Point, Quebec, from 29.84 inches on the morning of the 15th to 30.38 inches by the morning of the 17th. The retrograde movement of this storm began during the afternoon of the 16th, when pressure over the mouth of the St. Lawrence was 30.32 inches and rising. The pressure distribution along the track of the cyclone of April 21–24, 1910, differs in some details from that of the two storms above considered, but it is similar in that pressure over the Canadian Maritime Provinces was rising at the time the cyclone began its abnormal path. The large sweep of the latter from its position near Madison, Wis., on the evening of the 23d to Nashville, Tenn., is an illustration of cases, not infrequent, when the apparent movement may not be real. Pressure rose sharply in the center of the cyclone in the 12 hours 8 p. m., 23d, to 8 a. m., 24th; at the same time a katallobar moved from Oklahoma to Nashville, Tenn., by the 8 a. m. observation of the 24th; these two events—rising pressure in the cyclone center and falling pressure to the southeast—conspired to give the lowest pressure at Nashville, although pressure was still lower to the east, as in North Carolina. As between the two propositions, first, that the cyclonic system of winds and pressure was transferred bodily from Madison to Nashville, or second, that the original cyclone was destroyed by rising pressure—filled up, as it were—and that a secondary cyclone

formed to the southeast, the formation of which was facilitated by the arrival of a katallobar from the west, I would say that the second appears to be the most probable, but, however that may be, the fact remains that the northeastward progress of the cyclone was interrupted on the 23d, probably by the filling up of the cyclone *in situ* and the development of anticyclonic conditions—rising pressure over the Canadian Maritime Provinces. The cyclone of April 14–16, 1903, only remains to be examined. In this case the cyclone advanced to southern New Jersey by the morning of the 15th; it then made a loop to the west, continuing its turning motion counterclockwise and passing over the Virginia capes to sea on the early morning of the 16th. The pressure at Sydney, Cape Breton Island, directly in its normal path, rose from 29.78 inches on the morning of the 13th to 30.20 inches on the morning of the 15th at the time the abnormal course of the cyclone began.

I am unable to offer any suggestion as to the cause of the loop in the tropical storm of October, 1910, although logically its progressive movement should be subject to the same disturbing influences as are operative in the case of extratropical cyclones.

REMARKS UPON THE INTERPRETATION OF ALLOBARIC CHARTS.

The series of allobaric charts of the Weather Bureau now extends upward of 40 years and a considerable number of forecasters have had greater or less experience in the application of the information conveyed by these charts to the practical problem of weather forecasting from synoptic charts.

At least 95 per cent of this experience is lost to future workers because of the failure on the part of those possessed of the experience to commit it to writing.

The natural disinclination to reduce their precepts to writing may be explained on the assumption that there was and is a lack of any clear understanding of the physical phenomena which form the foundation of these charts.

Everyone who has given attention to the subject knows that falling pressure is an almost invariable accompaniment of cyclones and that, conversely, rising pressure, in a somewhat less degree, is an accompaniment of anticyclonic winds and pressure distribution. Rising pressure is sometimes, as it seems, merely the local reaction toward higher pressure, in which case it probably does not extend upward to any considerable altitude and does not signify the oncoming of anticyclonic conditions.

It is also a commonplace in the experience of forecasters that the intensity of development of strong cyclonic and anticyclonic conditions is measured by the rapidity with which the changes in surface pressure take place and also in a lesser degree to the geographic extent covered by them.

These two general conclusions may be regarded as fully established on the ground of human experience; when, however, we attempt to penetrate beyond their immediate range the limit of our knowledge is remarkably small. The literature of the subject is not large; that available to readers of this REVIEW is summarized by Dr. Hanzlik.[1]

It is to Ekholm, however, that we are indebted for much of the literature on the subject, especially as it applies to European cyclones. In a recent communication to the Weather Bureau Ekholm points out that the summary of Sresnewsky's work as quoted by Hanzlik is best expressed as follows when translated into English:

> From 23 instances he finds that the strongest fall of the barometer is going on, not in the path of the cyclone, but to the right of it, and that the future course of the center of the cyclone is directed not toward the place where the barometer is falling most strongly, but to the left of it. According to Sresnewsky this is explained by the great eccentricity of the outer isobars of the cyclone, the isobars on the right side of the cyclone being much nearer to each other than on the left side. There are, however, many exceptions to the rule. On this point Sresnewsky remarks: Relatively frequently it occurs that the minimum (cyclone) moves directly to the point where the barometer fell most strongly at the preceding term; sometimes, however, the distance between the center of the minimum and the point [place] of the greatest fall of the barometer becomes extraordinarily large. Thereby it happens that the connection between the minimum and the falling of the barometer becomes totally disturbed; the minimum remaining immobile at a point; the rarefaction of the air propogates itself in the form of a wave in any direction, going away more and more from the minimum.

The experiences of forecasters in the United States, are, I think, in general accord with the foregoing, except the last sentence, and in regard to that it is not clear what is meant by "the rarefaction of the air propagates itself in in the form of a wave in any direction, going more and more from the minimum."

The following suggestion by Hanzlik[2] commends itself to the writer:

> I am inclined to believe that in the areas of fall and rise we have found something independent of the LOW, something primary, and that the LOW, by its distance from them, regulates its own velocity. * * * I would bring these moving areas of falling and rising pressure in close connection with both the currents producing the LOWS, namely, the cold northerly winds with the areas of rise, and the warm southerly winds with the areas of fall, because, first, the extreme temperature changes lie within the areas of rise and fall, and second, these two currents are the primary cause of the LOW.

When it is considered that the axis of the LOW is inclined backward, at a considerable angle, we may well inquire is the fall in pressure which is portrayed on allobaric charts to be referred to the very lowest levels in the superincumbent air or perhaps to the 4, 5, or 6 kilometer level? In other words, at what level in the free air is the action going on that results in a fall in surface pressure and also, in a manner not clearly understood, forms the guiding force in the progressive motion of the cyclone? Another problem which forces itself upon the forecaster is how shall he explain the fact that areas of falling pressure are not coextensive, on the surface at least, with the cyclones to which they belong? The north-south extension of areas of falling pressure is many times greater than its east-west extension, and somewhere at the intersection of the two axes the fall or rise in pressure, as the case may be, is at a maximum, diminishing thence in all directions.

As Hanzlik has already pointed out, there is an almost unworked field of study in a correlation of the movement of cyclones and anticyclones and the areas of falling and rising pressure that accompany them.

In conclusion, three points in connection with the abnormal paths in Figure 1 stand out prominently: First, that the temporary blocking in the path of the cyclone in every case takes place in the neighborhood of a water surface; second, that the turning in the path of the cyclone is in a counter-clockwise direction, and third, that in each case of temporary blocking, excepting only the tropical storm of October, 1910, pressure rose over the Canadian Maritime Provinces. In my opinion the last named is the most probable cause of the erratic movement as described and illustrated.

[1] Hanzlik, S., Relations between velocities of progression of lows and the areas of rising and falling pressure that accompany them. MO. WEATHER REV. 34: 205.

[2] *Loc. cit.*, p. 208.

ELEVATION AND ALTITUDE.[1]

Engineers use the word *elevation* with reference to the height of an object, usually on the ground, relative to some sea level or some other fixed datum. In aerology and aviation, heights above ground in free air are commonly referred to as *altitudes*. In meteorology and other scientific discussions, heights either on the ground or above it are sometimes referred to indifferently as elevations or altitudes and the terms are often used interchangeably. In the table of stations in the reports of the U. S. Weather Bureau, height of ground above sea and height of instruments above ground are both referred to as elevations. Such uses of the word elevation are sometimes confusing. Cases have arisen where it was difficult to ascertain whether the height of an instrument, anemometer, barometer, or thermometer, for example, was with reference to sea level or ground level. Of course, this uncertainty could only exist at stations near sea level. It is suggested that a distinction in usage of the terms elevation and altitude, somewhat akin to that suggested by Dr. H. R. Mill for the terms mean and average,[2] may be desirable. Would it not be well to limit the use of the term altitude to heights above ground at a particular location, and the use of the term elevation to the height of the ground or a fixed object on the ground with reference to sea level, or some other definite datum, the actual point of reference being near or remote, as the case may be. On this basis the height of a meteorological station would be given as its elevation and would be the ground level elevation at the station. The heights of the instruments above ground would be expressed as altitudes.—*Robert E. Horton.*

[1] The suggestion by Mr. Horton is an excellent one, and I may express the hope that it will be uniformly adopted by writers for the REVIEW. In the beginning it would be well for each writer to announce on the occasion of the first use of either of the terms "elevation" or "altitude" the sense in which it is used. The official publications of the Weather Bureau where the expression "elevation" appears make it clear what reference point is taken as a base level.—EDITOR.

[2] Cf. MO. WEATHER REV., November, 1918, 46: 514-515.

TEMPERATURES OF THE SOIL AND AIR IN A DESERT.

By JOHN G. SINCLAIR.

[Medical School, University of North Dakota, March 15, 1922.]

The Carnegie Institution of Washington maintains a Desert Laboratory at Tucson, Ariz., where for some years the activities of plants and animals in relation to their desert environment have been studied. Much work has been done with water relations both as to evaporation and movement in soils. Extensive records of soil and air temperature are kept.

While assistant in charge of Professor Tower's "Experiments in Evolution" (see Carnegie Publication No. 263) I undertook a further analysis of the temperature conditions of air and soil. The results have a meteorological as well as a biological interest.

It is a well-recognized fact that the range of temperatures in the desert is tremendous. The surface of the soil is heated and it is a matter of interest to know to what extent this heat is transferred to deeper levels. It is well known that the surface air becomes rapidly chilled in the evening. What is the relation of temperature here to the levels above and the soil beneath? Desert animals and plants live in a comparatively narrow zone.

There were available at Tucson an exceptional aggregation of thermometers. The measurements in air were taken with German-made instruments, having large bulbs and graduated to tenths of a degree centigrade. These instruments were divided into two sets. One set was coated with a glossy white paint and the other with a dull black. I anticipated criticisms of this and so took the precaution to read the standard shelter thermometer at the same time that any other readings were taken. Since they were to be used in the open sunlight, the entire lot were standardized. To do this they were placed at a uniform level about 4 feet above ground and readings were taken every hour of the day. The thermometers were inclined, so that their axes were at right angles to the circle of the sun, insuring uniform exposure at all times. The members of each set differed only by tenths of a degree from each other. The constant necessary to reduce each to the median member of the group was adopted for each thermometer and for each hour of the day separately. All further data were then corrected by these constants.

The soil temperatures were read on standard mercury thermometers, which, like the others, had to be checked in a water bath for comparison. It was found necessary to use a boiling-point thermometer for the surface soil, as the temperature there burst the one first employed. At two of the levels Friez soil thermographs registered continuously and the records from other instruments were available for comparison but from a different locality.

Figure 1 illustrates in diagram the apparatus set up. The levels of the black and white thermometers were the same and the exposure was made uniform through the day as in the tests. The upper six soil thermometers were permanently embedded and were read in place. The depth indicated the distance to the center of the bulb. The thermometers for the deeper levels were slipped into close-fitting glass tubes, so that the bulbs rested in molds in the soil below. These were drawn up rapidly by strings sufficiently high to be read and were immediately dropped back and the tube corked.

After the preliminary tests the reading began at 5:30 a. m., June 17, 1915, and continued almost hourly to 10:30 p. m. The series was repeated nearly daily till September 19, 1915. An inspection of the data showed a repetition of the main features daily. For this reason that day was chosen for presentation which showed the highest temperature reached for the year. This was June 21, 1915.

Table 1 shows the data taken June 21. In the table the data for air and soil temperatures are separated at the ground level. At this point are placed the readings of the standard shelter thermometer and as a matter of added interest readings taken in shade among the red volcanic rocks of the Desert Laboratory grounds. All the apparatus except this one thermometer recorded the conditions in the adobe soil of the garden well away from the rocks. The maximum temperatures reached in the air series at any time of day are in bold-faced type and are arranged to compare the black and white thermometers with the standard shade temperature.

The minimum temperatures for any time of day are given in italics. The peculiar shift of the point of maximum and minimum temperatures is a significant problem. At 4:30, when this shift occurs, the sun is still high and the earth is much hotter than the air immediately above it.

The temperatures of the soil series in bold-faced type are the maxima for that level for the entire day and the minima for the day are underlined. Here the steady progress of the heat downward is graphically shown. The minima are underlined. The minima for the levels 2 cm. and 4 cm., of course, occur before 5:30 a. m.

TABLE 1.—*Temperture data (° C.) for June 21, 1915, Desert Laboratory, Ariz.*

		5:30 A		6:30 A		7:30 A		8:30 A		9:30 A		10:30 A	
		B	W	B	W	B	W	B	W	B	W	B	W
Air levels in centimeters above the ground level.	175	12.0	12.0	26.6	18.8	30.6	24.8	37.7	32.0	41.1	35.6	42.7	38.4
	114	11.4	11.2	27.5	18.9	32.7	25.5	40.2	32,3	43.9	36.5	45.6	38.9
	65	10.7	10.2	27.8	19.0	32.8	26.2	41.7	33.3	44.8	36.9	46.7	40.0
	32	10.3	10.0	27.4	18.8	34.4	26.8	42.8	35.0	46.9	39.5	48.3	41.9
	12	10.2	9.7	27.8	19.4	35.6	27.9	44.0	36.1	48.3	40.9	50.3	43.6
	4	10.0	9.6	28.6	20.0	36.0	28.1	45.8	37.1	50.3	41.7	53.1	43.6
Standard shade		....	11.6	....	19.8	....	25.4	....	30.6	....	35.7	....	38.4
Shade among rocks		22.0	....	25.0	....	28.2	....	30.6	....	32.5	....	35.0	....
Soil levels in centimeters below ground level.	0.4	....	17.0	....	23.3	....	31.8	....	43.5	....	54.2	....	62.1
	2	....	22.0	....	22.7	....	26.9	....	32.3	....	37.8	....	40.4
	4	....	23.5	....	23.5	....	26.1	....	29.9	....	34.3	....	37.1
	7	....	25.8	....	25.2	....	26.2	....	28.4	....	31.2	....	33.8
	10	....	28.1	....	26.3	....	27.2	....	27.9	....	28.2	....	30.7
	15	....	30.2	....	29.6	....	28.1	....	28.9	....	28.8	....	29.1
	20	....	30.6	....	30.1	....	29.8	....	29.4	....	29.2	....	29.0
	30	....	29.7	....	29.5	....	29.3	....	29.2	....	28.7	....	27.9
	45	....	27.8	....	27.8	....	27.8	....	27.8	....	27.9	....	27.9
	60	....	26.4	....	26.4	....	26.4	....	26.4	....	26.4	....	26.4
	100	....	24.5	....	24.5	....	24.5	....	24.5	....	24.5	....	24.5
	200	....	20+	....	20+	....	20+	....	20+	....	20+	....	20+

		12:00		1:00 P		2:00 P		3:30 P		4:30 P		6:00 P		7:30 P		9:00 P		10:30	
		B	W	B	W	B	W	B	W	B	W	B	W	B	W	B	W	B	W
Air levels in centimeters above the ground level.	175	43.8	41.5	46.9	41.6	44.1	41.5	46.0	42.7	47.2	42.6	40.4	38.8	31.7	31.8	24.3	24.3	20.5	20.5
	114	46.9	39.9	48.7	42.7	46.1	41.5	48.3	42.8	48.6	42.6	38.7	38.0	30.8	30.7	23.7	23.7	19.5	19.5
	65	48.1	41.8	50.8	44.0	47.5	42.4	48.6	43.6	49.8	43.2	37.6	36.7	29.6	29.4	22.8	22.8	18.4	18.4
	32	50.1	43.0	53.3	45.8	49.1	44.3	50.7	45.0	50.5	44.3	36.0	35.8	28.5	28.7	21.9	21.9	18.3	18.3
	12	52.2	44.4	55.7	48.4	52.2	46.3	53.0	46.7	47.7	43.2	36.2	35.0	27.9	27.8	21.4	21.4	18.1	18.1
	4	53.9	46.4	57.5	49.7	52.0	47.8	55.7	48.6	47.8	43.8	35.8	35.6	27.9	27.8	21.5	21.5	18.2	18.2
Standard shade		....	40.7	....	42.5	....	42.2	....	42.0	....	41.5	....	38.7	....	31.8	....	24.8	....	19.8
Shade among rocks		36.0	....	40.1	....	42.0	....	42.5	....	44.0	....	38.5	....	34.0	....	30.5	....	23.0	....
Soil levels in centimeters below ground level.	0.4	....	58.3	....	71.5	....	70.2	....	67.8	....	62.8	....	49.3	....	39.2	....	31.8	....	27.4
	2	....	45.8	....	50.4	....	62.1	....	52.5	....	51.0	....	43.5	....	38.1	....	32.9	....	29.5
	4	....	41.4	....	45.4	....	47.3	....	48.1	....	47.5	....	43.1	....	38.8	....	34.2	....	31.0
	7	....	37.1	....	40.5	....	42.7	....	43.8	....	44.1	....	42.2	....	39.6	....	35.9	....	33.0
	10	....	33.0	....	35.5	....	37.6	....	39.1	....	40.1	....	40.1	....	39.0	....	35.8	....	34.5
	15	....	29.9	....	30.8	....	32.0	....	33.1	....	34.4	....	35.4	....	35.6	....	35.3	....	34.4
	20	....	29.2	....	29.7	....	30.2	....	31.0	....	31.9	....	32.9	....	33.2	....	33.4	....	33.2
	30	....	27.8	....	28.7	....	28.7	....	28.7	....	28.8	....	29.1	....	29.3	....	29.5	....	29.8
	45	....	27.9	....	27.9	....	27.8	....	27.8	....	27.8	....	27.8	....	27.8	....	27.8	....	27.8
	60	....	26.4	....	26.4	....	26.4	....	26.4	....	26.4	....	26.4	....	26.4	....	26.4	....	26.4
	100	....	24.5	....	24.5	....	24.5	....	24.5	....	24.5	....	24.5	....	24.5	....	24.5	....	24.5
	200	....	20+	....	20+	....	20+	....	20+	....	20+	....	20+	....	20+	....	20+	....	20+

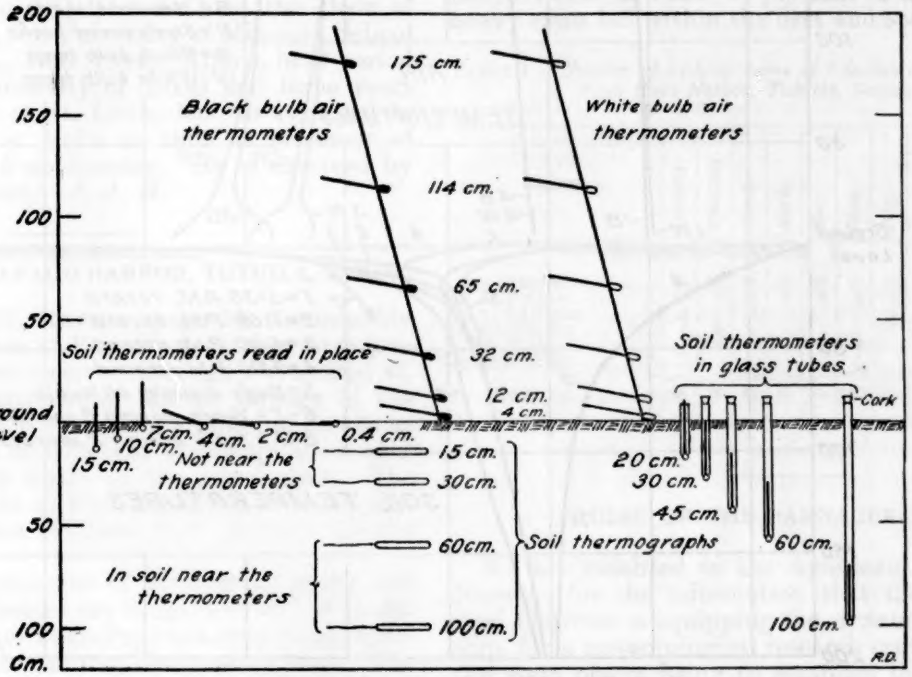

FIG. 1.—Arrangement of apparatus for measuring temperatures in the soil and lower strata of the air.

Figure 2 is a picture of the most interesting records of the day. The graphs are self-explanatory, except at two points. The short sections of the curves at 7 and 8 are taken from thermograph records made in different soil and among the rocks. The conserving of heat is well illustrated here.

Table 2 presents certain facts concerning the daily range in comparison with the annual range at different levels. It also shows the progressive movement of heat into the ground.

These data present problems which are not easily solved. The outstanding feature of the ground series is the tremendous daily and yearly range of surface temperatures. It so happens that the daily range is so nearly the yearly range that the effects are not transmitted much beneath the surface, and a relatively moderate and constant temperature is quickly reached. For this reason it is important biologically to know how deep desert animals burrow to æstivate or hibernate, as the case may be.

TABLE 2.

	June 21, 1915.				Annual temperatures.			Daily range.	Annual range.
	Max.	Time.	Min.	Time.	Maximum.		Minimum.		
	° C.		° C.		° C.			° C.	° C.
Shelter	42.5	1 p. m.	11.0	4-5 a. m.	42.5	1914-1915	.3°C.1914-15	31.5	42.2
Soil .4 cm	71.5	1 p. m.	15.0	4-5 a. m.	71.5	June 21		56.5	
Soil 2 cm	62.1	2 p. m.	22.0	5 a. m.	62.5	June 25		40.1	
Soil 4 cm	48.1	3.30 p. m	23.5	5.30 a. m	50.2	July 8		24.6	
Soil 7 cm	44.1	4.30 p. m	25.2	6 a. m.	46.1	July 9		18.9	
Soil 10 cm	40.1	6 p. m.	26.3	6.30 a. m	42.2	July 10		13.8	
Soil 15 cm	35.6	7.30 p. m	28.1	7.30 a. m	37.0	July 10	3° Aug. 1904-1914.	7.5	34.0
Soil 20 cm	33.4	9 p. m.	29.0	10.30 a. m	35.0	July 11		4.4	
Soil 30 cm	29.8	10.30 p. m	27.8	12 a. m.	31.6	July 12	9° Aug. 1904-1914.	2.0	22.6
Soil 45 cm	27.9	10 a. m.	27.8	2 p. m.	29.7	July 20		0.1	
Soil 60 cm	26.4		26.4		29.0	Aug. 10	15° 1915		14.0
Soil 100 cm	24.5		24.5		27.0	Aug. 16	18° 1915		9.0
Soil 200 cm	Nearly constant temperature throughout the year; about 20° C.								

The graphs of air temperature show an inclination at night opposite the daytime. Notice that there is practically no difference between the black and white thermometers during the night and that in that period four thermometers at each level register 2° C. difference in the height of a man, his feet being colder than his head. The ground beneath is warmer than the air at any point above. I am unable to explain this anomalous condition. The temperature gradient is reversed at 4:30 p. m. A study of the graphs 3B and 3W of Figure 2 shows a chill at the ground surface itself and in the face of a bright sunlight. The phenomena can not be explained readily by air movement because there is very little movement, and the point of maximum temperature is only 30 cm. above the surface. In all the graphs the standard shade temperature corresponds closely but with the upper levels recorded on the white thermometers. The heat-conserving action of the rocks is again shown by the shade readings taken among them at the same time.

Two applications are worth making. The terrific forces involved in the merely surface expansion and contraction of rock may be a very potent factor in their disintegration. The reversal of the temperature gradient, to whatever cause it may be due, may lay the foundation, for the later large displacement of air known as cold-air drainage on a level desert.

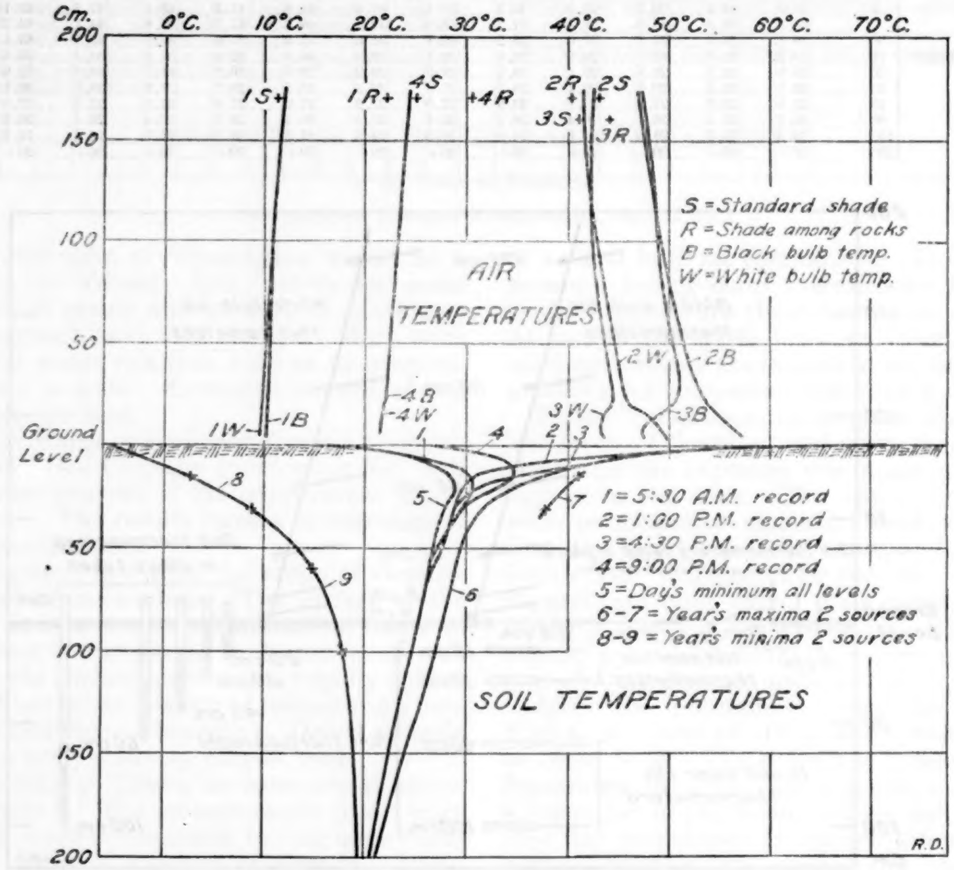

FIG. 2.—Curves of diurnal changes in soil and air temperatures.

DAMAGE TO WIRE SERVICE BY HEAVY SNOWSTORM IN KANSAS.

A heavy fall of wet, clinging snow that fell on March 9–10, 1922, over a strip about 50 miles wide extending from the northeast corner of Kansas to the south central part, near Hutchinson, resulted in damage to telephone and telegraph lines almost without precedent in the State. Sleet and ice accumulations on wires have frequently broken down pole lines in past years, serious trouble of this nature due solely to snow was a new experience to linemen, even when it fell to a depth of a foot or more, as it did in the central counties during this storm.

The snow occurred with temperatures somewhat below freezing and a high wind, estimated at 45 miles an hour, that packed it solidly against the north side of wires, poles, and other objects. In the Hutchinson district, where the damage was most severe, a cone-shaped mass of snow projected along the north side of every pole. The wind also packed the snow against the north side of each wire until the weight of the accumulation was sufficient to turn it partly over, exposing another surface to the wind. In this way wires were turned back and forth until they were completely coated with cylinders of packed snow that in some cases measured 2½ inches in diameter.

A single copper wire, No. 12 gauge, N. B. S., 1 foot long, with its incasing cylinder of snow, was carefully removed by linemen of a telephone company after the storm and found to weigh a pound. With a 30-wire lead, which is not unusual in an important line, and poles at the standard distance of 130 feet, this would mean a weight of 3,900 pounds, or almost 2 tons, on each pole.

This immense weight at a time when a high wind was blowing broke off thousands of poles, and wires were also broken and tangled. The Southwestern Bell Telephone Co. reported a loss of 5,000 poles and an estimated damage of $200,000, while the Western Union Telegraph Co. and the United Telephone Co. were also heavy losers.

Hutchinson, the second largest city in the central portion of the State, was completely isolated, as far as wire service was concerned, for more than 24 hours and without service in its local telephone service for six days. Complete service in some of the less important leads in the district was not restored until more than two weeks after the storm.—*S. D. Flora.*

NOTES, ABSTRACTS, AND REVIEWS.

Austin Lee McRae, 1861–1922.

We regret to announce the death of Prof. A. L. McRae, which occurred at Rolla, Mo., March 18, 1922, at the age of 60 years.

Professor McRae will be remembered by the older members of the Weather Bureau as a colleague of McAdie, Morrill, and Schultz in the early eighties in investigations upon atmospheric electricity. While stationed at Boston he studied under Prof. John Trowbridge, of Harvard University, and received the degree S. D. from that institution in 1886. In addition to service at Boston, he was on duty at Columbus, Ohio, Terre Haute, Ind., Rapid City, S. Dak., and Columbia, Mo. At the last-named station he perfected arrangements whereby the State Weather Service of Missouri, organized in 1877 by Prof. F. E. Nipher, of Washington University, and supported by private means, was taken over by the National Weather Service in cooperation with the State Board of Agriculture of Missouri. Professor McRae was the first director under the reorganization. He resigned from the Signal Service in August, 1891, to engage in teaching in the University of Missouri; later he held the chair of professor of physics at the University of Missouri, School of Mines, at Rolla, Mo., 1891–1894. After a brief period of teaching in the University of Texas and three years as consulting engineer in St. Louis, Mo., he returned to the School of Mines at Rolla in 1899 as professor of physics and since 1915 as director. He is survived by a wife and three children.—*A. J. H.*

HEAVY RAINS AT PAGO PAGO HARBOR, TUTUILA, SAMOA.

In the January, 1922, REVIEW, page 26, the monthly amounts of precipitation at Pago Pago Harbor were presented. We have now received through Dr. Alfred G. Mayor, Director Department of Marine Biology of the Carnegie Institution of Washington, additional details as to the frequency and distribution of precipitation of 2 inches and over in 24 hours at the same place. The observations were made at the United States naval station under the direction of Lieut. F. C. Nyland, United States Navy.

Tutuila is the southernmost of the Samoan group and its geographical coordinates are S. lat. 14° 18′; W. long. 170° 41′. The harbor of Pago Pago is a deep indentation on the south coast, which almost bisects the island. The harbor is encompassed by mountains; a sharp peak to the westward reaches an altitude of 2,133 feet above sea level; directly to the eastward another peak rises to an elevation of 1,719 feet.

The average annual precipitation of Pago Pago is 196 inches (21 years' record). The greatest annual amount in that time was 284.4 inches; the least 130.1; the greatest monthly amount was 60.5 inches, in May, 1913; the least, 0.1, in June, 1900. The greatest 24-hour amount was 20 inches, in May, 1912; other large daily amounts were 16.5 inches, in June, 1920, and November, 1908; 15.9 inches, in September, 1914.

These amounts compare very well with other large daily rains in the Tropics. Java, for example, has a record of 20.12 inches in 24 hours at Besokor, a plains station at an elevation of but 45 m. above sea level.

Greater amounts than those mentioned are occasionally recorded in temperate latitudes far removed from the ocean.

The winds of the Samoan group.—The southeast trades blow from the middle or end of April to November, diminishing in strength and steadiness during the last half of the winter. In July and August—winter months in the Southern Hemisphere—the southeast trades are fresh and at times squalls prevail. The two months named are the months of least average rainfall, although in some seasons heavy rains fall even then. The winds during the remainder of the year are, in general, easterly. At times, however, westerly winds and calms prevail.

In general, it would seem that the heavy precipitation of Tutuila as compared with Apia, on the north side of Upola, must be due to the topography of the first named and the fact that Pago Pago is practically an inland rather then a coast station.

In the table below will be found the total number of rains of 2 inches and over in 24 hours, arranged by months and groups or classes. The latter range from 2–4.5 inches at the lower end to 15–20 inches at the upper end. It will be seen that 80 per cent of the heavy rains fall within the first class and that 94 per cent of the total number of heavy rains fall within the first and second classes.

TABLE 1.—*Number of 24-hour rains of 2 inches and over (1900–1921) at Pago Pago Harbor, Tutuila, Samoa.*

Classes.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
													P. ct.
(1) 2–4.5 inches	45	60	56	45	30	37	16	21	33	42	47	53	80
(2) 4.6–7 inches	15	5	7	8	5	5	2	2	7	7	15	5	14
(3) 7.1–9.5 inches	3	4	2	2	0	3	1	....	1	1	3	1	3
(4) 9.6–12 inches	1	3	....	....	1	1	3	....	1	....	0	0	2
(5) 12–15 inches	....	1	....	....	1	0	....	....	0	....	0	1	.....
(6) 15–20 inches	....	....	....	....	....	1	....	....	1	....	1	....	.....
Total	64	73	65	55	37	47	22	23	43	50	66	60	.....

—*A. J. H.*

CRUISE OF THE "ARNAUER HANSEN."

We are indebted to the American consul at Bergen, Norway, for the information that the Bergen Geophysical Institute is equipping the *Arnauer Hansen*, a motor ship, for a meteorological research cruise in the Atlantic, the main object being to establish the practicability of issuing weather forecasts for the Atlantic.

The *Arnauer Hansen* is being fitted out at Bergen, and its cruise will be financed by the Norwegian Government and Bergen shipping interests. Professor Helland-Hansen, chief of the Bergen Geophysical Institute, and Chief Calwagen, of the Bergen Observatory, will accompany the expedition, which will set out from Ostend early in May.—*A. J. H.*

THE JAN MAYEN METEOROLOGICAL STATION.

Through the courtesy of the American consul at Bergen, Norway, we are able to announce that the meteorological station established on Jan Mayen in the autumn of 1921 will be taken over by the Norwegian Government on May 1, 1922. Jan Mayen is an isolated rock in the Arctic Ocean, nearly midway between North Cape and

Greenland. The meteorological station there was founded through the efforts of the Bergen Geophysical Institute by private subscription and some assistance from the Norwegian Government.—*A. J. H.*

BULLETIN OF THE CUBAN NATIONAL OBSERVATORY.

We are glad to note the enlargement of the Cuban National Observatory Bulletin published by the Department of Agriculture, Commerce, and Labor. This bulletin, which formerly carried a formal review of the weather and crops, now includes articles on various meteorological topics, as well as data of daily meteorological observations in considerable detail for the national observatory and monthly summaries of temperature and precipitation for 26 substations throughout the island.

The enlarged publication is a welcome addition to the literature on tropical meteorology.

METEOROLOGICAL SERVICE FOR COLOMBIA.

Meteorologists throughout the world will be glad to learn that the Republic of Colombia is organizing a national meteorological service, with headquarters at the observatory of Bogota. This service will be under the direction of the Rev. Simón Sarasola, S. J., founder and for 10 years director of the Observatorio del Colegio "Nuestra Señora de Montserrat," Cienfuegos, Cuba.

Very little meteorological or climatological work has heretofore been done in Colombia, even in comparison with the other regions of tropical Latin America, and the data to be collected by the new service will fill a serious gap in scientific literature. Moreover, a thorough climatological survey of Colombia will undoubtedly be of immense economic value to that country as an aid to the development of agriculture and the various industries. The Colombian Government is to be congratulated upon the important enterprise that it has undertaken, and it is greatly to be hoped that the other Latin-American Republics that now lack official meteorological organizations will follow Colombia's enlightened example.

FIRST AEROLOGICAL STATION IN BRAZIL.

We are indebted to Consul General Alphonse Gaulin, of Rio de Janeiro, Brazil, for the following:

According to an article which occurred in the Brazilian American of March 4, 1922, the Director of the Brazilian Meteorological Service has started the preliminary surveys for the construction of a kite station in the State of Rio Grande do Sul. * * * This appears to be the first step taken in regard to the proposed aerial lines between Rio de Janeiro and Porto Alegro.

WIND MEASUREMENTS IN THE LOWEST LAYERS.[1]

By ALBERT PEPPLER.

[Abstracted from *Beiträge zur Physik der freien Atmosphäre*, Band IX, Heft 3, pp. 114-129. 1921.]

The high radio towers at Nauen and Eilvese, Germany, afford exceptional opportunity, owing to their slender construction and consequent freedom from eddies and turbulence, for measuring the speed of the wind at various low levels in the atmosphere. Hellmann has investigated these conditions on the Nauen tower and the author now offers a discussion of the observations on the Eilvese towers, the highest of which is 250 meters.

The measurements were made at altitudes of 0, 2, 9.5, 16.5, 42, 82, and 124 meters above the ground. The anemometers were located on various towers of the radio station. This station is located in a level marshy region about 4 kilometers northeast of the Steinhuder Meer, and is therefore characteristic of the lowlands of northwest Germany.

The following phases of these observations are discussed:

(*1*) *The increase of wind speed with height.*—It is found that when the speed at 2 meters is plotted against the difference between the speed at the surface and at 2 meters the points fall on a parabolic curve. The formula of Hellman, $V_0 = V_2\ (h/2)^{\frac{1}{4}}$ for calculating wind speeds between surface and 2 meters agrees well with the Eilvese observations, especially when the speed is between 3 and 5 m. p. s. at 2 meters. Above 2 meters, the rate of increase of wind speed falls off quite rapidly, until above 16.5 meters it is almost linear, increasing about 2 centimeters per second per meter increase of altitude. The mean decrease of rate is shown as follows in cm. p. s. per meter of height:

	0-2	2-9.5	9.5-16.5	16.5-42	42-82	82-124
Eilvese	116	12	6	2	2	2
Nauen	104	10		4	2	

(*2*) *Comparison of vertical wind gradients in the north German lowlands with the Flanders coast.*—These comparisons are possible through observations made during the war. The anemometer at Brügge was located on a tower at an effective height of 80 meters above the surface. At Ostend observatory—on the coast, 22 kilometers distant—the anemometer was located at a height of 30 meters above the surface. The difference in wind speed between the two stations is in accord with the Nauen and Eilvese observations.

(*3*) *Diurnal variation of wind speed.*—The discussion embraces both cyclonic and anticyclonic weather, and it is shown that in anticyclonic weather the maximum wind speed occurs about midday and minimum just after midnight. The 124-meter curve, however, has its maximum just before midnight and its minimum just before noon. The curve for 42 meters is intermediate, showing the least amplitude of diurnal variation. The cyclonic curves are more nearly parallel, and show in all levels a maximum wind speed just after midday and a minimum just before midnight. In comparing the vertical wind gradient in cyclones and anticyclones it is found that between 2 and 16 meters above the durface the rate of increase is greater in cyclones than in anticyclones, but above 16 meters there is no essential difference.—*C. L. M.*

[1] *Windmessungen auf dem Eilveser Funkenturm.*

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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C. F. TALMAN, Professor in Charge of Library.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING MARCH, 1922.

By IRVING F. HAND, Temporarily in Charge.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**:225.

From Table 1 it is seen that direct solar radiation intensities averaged close to normal values for March at Santa Fe, N. Mex., and slightly below normal at the other three stations.

TABLE 1.—*Solar radiation intensities during March, 1922.*

WASHINGTON, D. C.

[Gram-calories per minute per square centimeter of normal surface.]

Date.	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Mar. 3	3.00				1.19						2.16
6	4.17		0.78	0.90	1.04		1.20	0.96	0.83	0.65	5.36
8	2.74						1.09				2.62
13	4.57		0.78	0.93	1.10						4.57
16	3.15		0.83	0.98	1.18		0.91	0.76	0.60		2.36
17	2.06		1.00	1.15	1.32	1.52	1.15	0.95	0.78	0.64	2.36
18	1.96		0.92	1.10							1.96
23	1.96		1.01	1.16	1.33	1.52	1.26	1.02	0.83	0.68	1.96
25	5.56				0.75		0.74	0.60			6.02
Means			**0.89**	**1.04**	**1.13**		**1.06**	**0.86**	**0.76**	**0.66**	
Departures			**+0.06**	**+0.08**	**−0.03**		**−0.06**	**−0.06**	**−0.04**	**−0.03**	

MADISON, WIS.

Mar. 2	1.19	0.92	1.02	1.16	1.33		1.34				1.60
3	1.96				1.20		1.23				2.74
4	2.74		0.90	1.10	1.31	1.57					3.81
11	3.63		0.56	0.77	1.07		1.05				3.81
13	6.27						1.15				7.57
15	2.62			1.19	1.35		1.26	1.08			2.49
21	2.26				1.32						2.49
22	1.96		0.86								3.30
Means		(0.92)	0.84	1.06	1.26		1.21	(1.08)			
Departures		−0.05	−0.19	−0.13	−0.06		−0.11	−0.08			

LINCOLN, NEBR.

Mar. 1	1.07		1.01	1.15	1.34	1.54					1.96
2	1.42				1.02		1.20	0.97	0.76	0.69	2.36
3	1.96	0.68	0.91	1.02	1.29	1.64	1.37	1.18	1.01	0.88	2.49
4	3.00		0.91	1.06	1.23						4.57
7	1.88		1.06	1.15	1.36						3.30
11	2.87			0.99	1.21						3.45
Means		(0.68)	0.97	1.03	1.24		(1.28)	(1.08)	(0.88)	(0.78)	
Departures		−0.21	+0.04	−0.05	−0.05		+0.02	±0.00	+0.05	±0.00	

SANTA FE, N. MEX.

Mar. 3	2.16									1.13	2.26
6	1.60				1.50	1.71					1.02
7	1.68			1.21	1.46	1.76					1.07
8	1.78		0.77	1.02	1.16						1.88
10	1.78			0.98	1.32						1.96
13	2.16						1.46	1.28	1.21	1.06	2.87
20	2.74			1.28	1.50	1.66					2.16
Means			(0.77)	1.12	1.39		(1.46)	(1.28)	(1.21)	(1.10)	
Departures			−0.41	−0.07	−0.05		+0.05	+0.01	+0.08	+0.04	

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged below the March normal at both Washington and Madison.

Skylight polarization measurements made on six days at Washington, give a mean of 56 per cent, with a maximum of 64 per cent on the 23d. These are about average March values for Washington. At Madison the value of 61 per cent obtained on the 21st is slightly below the normal for the month. Snow-covered ground prevented other observations at this station.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washton.	Madison.	Lincoln.	Washton.	Madison.	Lincoln.	Washton.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Feb. 26	206	377		−83	+92		−750	+1,052	
Mar. 5	273	296		−40	−13		−1,027	+960	
12	383	282		+45	−47		−715	+631	
19	337	273		−20	−72		−854	+228	
26	267	182		−105	−177		−1,591	−1,112	

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, April 29, 1922.]

In continuation of preceding publications, the following table contains the results for the solar constant of radiation obtained at Montezuma, near Calama, Chile, in February, 1922. The values of ρ/ρ sc are given at air mass 2, or if not the air mass is stated. The reader is referred for further statements regarding the arrangement and meaning of the table to the REVIEW for February, August, and September, 1919.

As stated in connection with the results for January, MONTHLY WEATHER REVIEW, February, 1922, **50**: 96, the observations of February were made entirely by the old or fundamental method, owing to the loss of part of one of the instruments in a high wind. It is expected that in March the short-method values will reappear.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. ρ sc.	V. P.	Rel. Hum.	Remarks.
1922 P. M.	*cal.*					*cm.*	*Per cent.*	
Feb. 10	1.910	E_0	VG	0.855	[1] 0.432	0.38	20	Clouds formed very near sun during last bolograph.
A. M.								
12	1.977	E_0	VG	.870	[2] .646	.42	42	Cirri in north.
13	1.938	E_0	VG+	.861	.576	.38	35	Clouds low in east and west.
15	1.967	E_0	VG+	.825	.381	.41	35	Cirri over high peaks.
18	1.996	E_0	VG	.835	[3] .422	.48	45	Cirri scattered about sky.
19	1.932	E_0	VG	.834	[4] .381	.62	64	Very heavy cumulus bank in north.
22	1.958	E_0	VG	.840	.400	.52	50	Cloudless.
23	1.930	E_0	E	.870	.465	.48	43	Cloudless.
24	1.969	E_0	VG	.855	.498	.53	48	Cloudless.
25	1.936	E_0	VG	.865	[5] .444	.63	62	Cloudless.
28	1.940	E_0	E−	.844	.499	.63	59	Cloudless.

[1] Air mass 2.57.
[2] Air mass 2.28.
[3] Air mass 1.86.
[4] Air mass 2.24.
[5] Air mass 1.83.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was somewhat above the normal at land stations on the Atlantic coast of Canada and the United States, including the Gulf of Mexico, as well as is in the Azores and Bermudas. It was practically normal at St. Johns, Newfoundland, and slightly below at Swan Island, West Indies, and on the southern coast of England. The North Atlantic or Azores HIGH was well developed during the greater part of the month, and there were only three days in which the barometric reading at Horta fell below 30 inches.

From reports received, fog was comparatively rare over the steamer lanes as well as in the British Isles, and over the Grand Banks.

Taken as a whole, the number of days on which winds of gale force were reported did not differ materially from the normal for March, which i considerably below that of February, although the frequency of gales during the month under discussion varied somewhat in different portions of the ocean.

Charts IX to XIV show the conditions from March 1 to 6, inclusive, with a well-developed LOW moving eastward across the ocean. This disturbance was at its greatest intensity on the 2d and 3d, when the greater part of the steamer lanes was storm swept. Storm logs follow:

British S. S. *Scythian*:

Gale began on the 1st, wind W. Lowest barometer 29.02 inches at noon the 3d, wind W., 9, in latitude 44° 47′ N., longitude 33° 29′ W. End on the 6th, wind SW. Highest force of wind 10, W.; shifts, SW.-WNW.-W.

Swedish S. S. *Stockholm*:

Gale began on the 1st, wind W. Lowest barometer 29.28 inches at 4 p. m. on the 1st, wind W., in latitude 44° 30′ N,. longitude 47° 20′ W. End on the 3d, wind WNW. Highest force of wind 10; shifts W.-WNW.-NW.-NNW.

British S. S. *Canadian Leader*:

Gale began on the 1st, wind SW. Lowest barometer 29.82 inches at 5 p. m. on the 1st, wind SW., 7, in latitude 50° 24′ N., longitude 22° 26′ W. End on the 2d, wind NNW. Highest force of wind 10, S.; shifts SW.-WNW.

Dutch S. S. *Lekhaven*:

Gale began Feb. 28, wind NW. Lowest barometer 29.86 inches at 1 p. m. on the 1st, wind WNW., 8, in latitude 38° 37′ N., longitude 58° 34′ W. End on the 2d, wind NW. Highest force of wind 10; shifts NW.-NNW.-NW.

British S. S. *Valacia*:

At 8 a. m. on March 2, wind increased to force 8, hauling to W., at 4 p. m. On the 3d wind steady from W., 9 to 10, until 11 p. m., then WSW., moderating. On the 4th wind S., increased to 9 at 3 a. m. and 10 at 11 a. m., then hauling to W., and WNW. by 2 p. m. Moderated in force from 6 to 8 p. m. Greenwich mean noon position on the 3d, latitude 48° N., 22° W.

British S. S. *Mackinaw*:

Gale began on the 2d, wind SW. Lowest barometer 29.25 inches at 4 p. m. on the 4th, wind SW., 11, in latitude 48° 45′ N., longitude 19° 05′ W. End on the 6th, wind NW. Highest force of wind 11, SW.; shifts SW.-W.-SSW.-W.-NW.

British S. S. *Bloomfield*:

Gale began on the 3d, wind SW. Lowest barometer 29.21 inches at 3 a. m. on the 4th, wind WSW., in latitude 43° 45′ N., longitude 35° 18′ W. End on the 5th, wind NNW. Highest force of wind 10; shifts W.-NW.-NNW.

American S. S. *H. M. Flagler*:

Gale began on the 4th, wind SE. Lowest barometer 28.52 inches at 2 p. m. on the 5th, wind S., 11, in latitude 59° N., longtidue 10° W. End on the 6th, wind SW. Highest force of wind 11, S.; shifts 8 points.

On the 5th there was also a disturbance of limited extent in the vicinity of Hatteras, as shown by following storm log.

American S. S. *Atlantic Sun*:

Gale began on the 5th, wind W. Lowest barometer 29.98 inches at 8 a. m. on the 5th, wind W., 9, in latitude 36° N., 73° W. End on the 6th, wind NNW. Highest force of wind 9; shifts W.-NW.-NNW.

On the 7th northerly winds of moderate gale force were reported by vessels in the Gulf of Mexico, and on that date and the 8th there were also two other disturbances of limited extent and intensity; one near Hatteras, and the second between the 40th and 45th parallels and the 40th and 55th meridians.

On the 8th the southern coast of England and northern part of France were visited by an exceptionally severe cyclonic storm. While this storm will be described elsewhere, the following reports from vessels that were in the vicinity at the time should prove of interest.

Capt. A. H. Barnes, master of the American tank steamer *S. B. Hunt*, states:

Attention is called to a cyclonic hurricane experienced on the morning of March 8, 1922, while off the Isle of Wight, bound east toward Hamburg. At 4 p. m. March 7, barometer read 29.82 inches (all barometer readings are uncorrected) and at midnight (civil time) a fresh breeze was blowing, barometer reading 29.46 inches. At 4 a. m. on the 8th it had become overcast and started to rain; wind increasing to whole gale force from the south and barometer falling to 28.28 inches. At 6:30 a. m. hove to under half speed, wind shifting to WSW., with hurricane force and working around to W., W. by N., and barometer rose to 29.04 inches and wind modified a trifle; at noon reading was 29.26 inches, wind force 8. This storm occurring in the English Channel caused a short, deep, quick, and ugly sea, so that the ship was awash continually and labored heavily. According to reports received at the time, this storm wrought considerable damage on both French and English coasts.

American S. S. *Deuel*:

Gale began on the 8th, wind SW. Lowest barometer 28.67 inches at 2 a. m. on the 8th, wind SW., 9, at Start Point, England (latitude 50° 13′ N., longitude 3° 38′ W.). End on the 8th, wind W. Highest force of wind 12; shifts SW.-W. Wireless report gives velocity of wind at 110 miles an hour; instruments then blown down.

American S. S. *Emergency Aid*:

Gale began on the 7th, wind SSW. Lowest barometer 28.93 inches at 4 a. m. on the 8th, wind SW., 11, in latitude 49° 30′ N., longitude 5° 22′ W. End on the 8th, wind NW. Highest force of wind 11, SW.; shifts SW.-WNW.

From the 9th to the 11th comparatively high pressure prevailed over the greater part of the ocean, with a few reports received from widely scattered localities, where moderate gales were encountered.

On the 12th a disturbance appeared central near latitude 40° N., longitude 55° W., and severe gales were reported by a number of vessels between the 40th meridian and the American coast. This LOW moved slowly northeastward, and on the 16th the center was near latitude 48° N., longitude 33° W. Storm logs follow:

British S. S. *Bristol City:*

Gale began on the 12th, wind S. Lowest barometer 29 inches at noon on the 13th, wind NW., in latitude 43° 10′ N., longitude 45° 55′ W. End on the 14th NNW. Highest force of wind 12; shifts N-NNW.

Norwegian S. S. *Foldenfjord:*

Gale began on the 11th, wind SW. Lowest barometer 29.16 inches at 6 a. m. on the 13th, wind SW., 11, in latitude 40° 56′ N., longitude 46° 05′ W. End on the 14th, wind NW. Highest force of wind 12; shifts SW.-W.-WNW.

British S. S. *Lexington:*

Gale began on the 12th, wind SSE. Lowest barometer 29.06 inches at midnight on the 13th, wind S., in latitude 46° 27′ N., longtiude 41° 27′ W. End on the 14th, wind N. Highest force of wind, 11; shiftt SSE.-S.-SW.-W.

British S. S. *Kenbane Head:*

Gale began on the 15th, wind W. Lowest barometer 29.22 inches as 10 a. m. on the 15th, wind WNW., 10, in latitude 43° 16′ N., longitude 46° W. End on the 16th, wind N. Highest force of wind, 11; shifts W.-WNW.

From the evening of the 15th until the morning of the 16th northerly gales again occurred off Hatteras, as shown by following report from American S. S. *El Estero:*

At 7 p. m. on the 15th in latitude 33° 03′ N., longitude 76° 46′ W., barometer 29.74 inches, wind NW., 7; rough and choppy sea, overcast and squally. At 7:30 p. m. wind shifted N., 9, sky clearing, frequent squalls, barometer rising. From 10 p. m. to 2 a. m. on the 16th, wind N., 10, clear since 10 p. m. At 2 a. m. on the 16th in latitude 33° 51′ N., longitude 76° 09′ W., barometer 29.89 inches, wind N., 10; very heavy and rough sea, weather clear. 10 a. m. fresh N. wind, end of gale.

On the 18th there was a LOW central near latitude 30° N., longitude 50° W., and northwesterly gales prevailed over a limited area in the vicinity of the Bermudas. This disturbance moved slowly eastward and by the 20th had apparently filled in, as it did not appear within the limits of the chart. Storm log:

American S. S. *Devolante:*

Gale began on the 18th, wind SSW. Lowest barometer 29.81 inches at noon on the 18th, wind SSW., 7, in latitude 37° 07′ N., longitude 46° 41′ W. End at midnight on the 19th, wind SSE. Highest force of wind 10; shifts S.-SSW. Continuous rain throughout the gale with heavy, rough sea.

A disturbance that was central near Philadelphia on the 20th moved northeastward, and on the 21st the center was near Eastport, Me. Southerly gales prevailed along the American coast on both of these dates, while on the 21st the storm area extended as far east as the 60th meridian. Storm logs:

Dutch S. S. *Alkmaar:*

Gale began on the 20th, wind S. Lowest barometer 29.58 inches at 8 p. m., on the 20th, wind SSE., 10, in latitude 34° 59′ N., longitude, 69° 34′ W. End on the 21st. Highest force of wind, 11, S.; shifts SSE.-S.-SSW.

Belgian S. S. *Gothland:*

Gale began on the 20th, wind SSE. Lowest barometer 29.70 inches on the 20th, wind SSE., in latitude 40° 40′ N., longitude 67° W. End on the 21st. Highest force of wind 10; shifts not given.

On the 22d and 23d the conditions were comparatively featureless, except that a few vessels along the European coast, between the 30th and 50th parallels, reported moderate northerly gales.

On the 24th and 25th a depression over Scotland was responsible for heavy weather in the region between 40° and 60° N., and 2° and 25° W. By the 26th the center of this LOW was somewhere over the North Sea, and winds of gale force were restricted to a small area in the southwest quadrants. Storm logs:

Norwegian S. S. *Ranenfjord:*

Gale began on the 24th, wind SSE. Lowest barometer 29.14 inches at noon on the 25th. in latitude 59° 33′ N., longitude 1° 35′ W. End on the 25th, wind ESE. Highest force of wind 11; shifts 4 points.

British S. S. *Vasconia:*

Gale began on the 24th, wind WNW. Lowest barometer 29.73 inches at 10 a. m. on the 26th, wind NNW., 10, in latitude 49° 27′ N., longitude 13° 19′ W. End on the 26th, wind NNW. Highest force of wind 10; shifts NW.-WNW.

On the 27th and 28th moderate weather prevailed over practically the entire ocean, with uniformly high pressure south of the 50th parallel.

On the 29th there was a disturbance of limited extent and intensity over the eastern part of the steamer lanes, accompanied by snow and hail.

On the 30th there was a LOW central about 10° east of St. Johns, Newfoundland. This remained nearly stationary during the next 24 hours, although increasing considerably in intensity and extent, as on the 31st, the storm area covered the region between the 35th and 50th parallels and the 40th and 50th meridians, while a few vessels experienced heavy weather outside these limits. Storm logs:

British S. S. *Alpine Range:*

Gale began on the 29th, wind WSW. Lowest barometer 29.36 inches at 10 a. m. on the 31st, wind NW., 9, in latitude 43° 21′ N., longitude 41° 13′ W. End on the 31st, wind NW. Highest force of wind 9; shifts WSW.-SW.-N.-NW.

American S. S. *Eastern Dawn:*

Gale began on the 31st, wind SSW., 7. Lowest barometer 28.83 inches at 8 p. m. on the 31st, wind SSW., 7, in latitude 43° 46′ N. longitude 39° 51′ W. End on April 2, wind NW. Highest force of wind 10, NNW.; shifts SSW.-NNW.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

The month of March opened with the North Pacific anticyclone somewhat southwest of its usual position and a well-defined depression over the Gulf of Alaska. By the 4th the anticyclone had extended eastward and was encroaching on the California coast, while the depression had moved inland and lost energy. A fresh depression appeared over the Aleutians. Following this date there was a general increase in pressure over middle latitudes of the eastern part of the ocean, an isobar of 30.50 inches appearing on the maps of the 6th-9th. During the same period the Aleutian depression moved slowly east-southeastward to the continent.

On the evening of the 11th pressure was rising strongly over the western Aleutians and a depression covered the Gulf of Alaska. The North Pacific anticyclone was south of its usual position. On the morning of the 13th the barometer at Dutch Harbor stood at 30.60 inches. Pressure continued above normal in this region until the 22d, while a depression of varying intensity lingered near the British Columbia coast. During this period the anticyclone moved inland on the California coast and a depression formed in its rear, apparently on the 18th, near the Hawaiian Islands. This latter depression moved leisurely east-northeastward to the continent, passing inland on the 23d.

The high pressure over the Aleutians gave way on the 23d to a depression from the westward, and thereafter to the close of the month this region was covered by a great cyclone, in the eastern part of which a series of depressions formed and moved east-southeastward to the continent. On the morning of the 31st the barometer at Dutch Harbor registered the low reading of 28.20 inches, approximately 1.56 inches below normal.

Over the western part of the ocean meanwhile a steady stream of depressions of varying magnitude was moving eastward, after having passed over or near Japan. During the period from the 1st to the 24th no fewer than 19 separate disturbances were charted by the Imperial

Marine Observatory at Kobe. Some of these combined, however, as they progressed eastward. Among the more important of these disturbances may be mentioned the following: The depression which traveled along the south coast of Japan on the 4th, eastern time; one which moved from the vicinity of Shanghai to the Okhotsk Sea, where it was central on the 18th; one which moved across the Japan Sea on the 20th, causing heavy gales, and disappeared east of the Kuril Islands on the 23d; one which passed over Japan on the 24th and moved northeastward across the Pacific. It is probable that still another depression quickly followed that of the 24th since the latter would scarcely account for the storm encountered on the 29th in longitude 167° E. by the Dutch S. S. *Arakan*, which will be referred to later.

The depressions on the Asiatic side during the first part of the month appear to have been directed either toward the Okhotsk Sea or the middle latitudes of the ocean. Those of the third decade traveled in the direction of the Aleutian Islands.

As a result of the cyclonic activity during the month many gales were experienced by vessels which furnish meteorological reports to the Weather Bureau. It is probable that the number of gales during the month was above the average, but a strict comparison is not possible with the data available. During the first week of the month they were chiefly reported from the region west of the 180th meridian, during the second and third weeks in mid-ocean, and in the last week west of the 170th meridian, W. longitude.

The following reports have been selected as representative of those received:

American S. S. *Pine Tree State* (since renamed *President Grant*), Capt. M. M. Jensey, Observer H. V. Van Dusen. While proceeding from Yokohama to Kobe the *Pine Tree State* was involved in the storm which passed along the south coast of Japan on the 4th, eastern time.

March 3, 33° 50′ N., 137° 10′ E., weather extremely sticky, inky clouds, very clear. Increasing easterly wind to strong gale, rough sea; barometer dropping fast but not far. March 4, 8:15 a. m. (L. M. T.), 33° 25′ N., 135° 30′ E., wind suddenly dropped to dead calm, very rough sea. Wind suddenly sprung up from north, whole gale. Visibility during this small typhoon very poor. Heavy rain at intervals.

Japanese S. S. *Mandasan Maru*, Capt. Tatsuzo Itoh, Yokohama for San Francisco.

Gale began on 4th, wind E., lowest barometer, 29.65 inches, occurred when in 39° 36.5 N., 147° 9.5 E., wind at time being ENE., force 9. Gale ended on 5th, wind NW.

American S. S. *West Jessup*, Capt. G. A. Whitehead, Observer C. Baker, Japan for Seattle. This vessel on the 12th was on the southern edge of a depression having its center over Sitka, Alaska, with a strong high-pressure area over the Aleutians and one of moderate strength northeast of the Hawaiian Islands.

Gale began on the 11th, wind W., lowest barometer, 29.83 inches, occurred at 6 p. m. of the 12th in 50° 10′ N., 145° 30′ W., wind at time NW. Highest force of wind 11, shifts W. to NW., gale ended 10 p. m. of 12th.

American S. S. *Bessemer City*, Capt. John Murphy, Observer R. B. Rogers, jr., Los Angeles for Yokohama. During the period from the 9th to the 16th, when between 174° 55′ W. and 155° E., this vessel experienced a succession of gales associated with the strong rise of pressure over the Aleutians. The highest force was recorded on the 16th, 11, WSW. The barometer at this time stood at about 28.93 inches, the vessel being in a depression in the rear of the anticyclone.

Dutch S. S. *Arakan*, Capt. Samuel Van Ronkel, Observer J. H. C. L. Baan, Manila for San Francisco. On the 29th the *Arakan* was involved in a deep depression, evidently the same one which appeared at Dutch Harbor on the 31st. Captain Van Ronkel has submitted a very complete report of this storm as observed on his vessel. The influence of the storm began to be felt on the 28th, when the *Arakan* was in 37° 52′ N., 160° 3′ E. The lowest barometer recorded was 28.47 inches at 5 a. m. of the 30th, the wind at the time being NW., 4. A remarkable feature of the storm, states Captain Van Ronkel was that neither the force of the wind nor its direction gave any indication as to the nearness or direction of the center. After the center had passed the wind freshened rapidly and by 11 a. m. was blowing with force 10–11 from WNW.

Date and hour.	Lat. N.		Long. E.		Bar.	Wind.	Weather.
Mar. 28:	°	′	°	′			
12 noon...	37	52	160	3	29.79	SW. by W., 4.	Overcast. Nb., 10.
4 p. m....	38	10	160	45	29.68	SW. by W., 5.	Sky var., clearing and overcast. Some rain.
8 p. m....	38	21	161	3	29.63	W., 5.........	Overcast. Nb., 10.
12 mid....	38	5	162	20	29.58	NNW., 2......	Nb., 10. Great humidity.
Mar. 29:							
4 a. m....	38	49	163	9	29.58	NNE., 1......	Nb., 10. Rain.
8 a. m....	39	3	163	52	29.46	ENE., 1......	Continuous rain............
12 noon...	39	5	164	33	29.21	E., 3.........	Nb., 10. Rain. Light SW. swell.
4 p. m....	39	27	165	13	28.92	SSE., 4.......	Same conditions.
8 p. m....	39	35	166	1	28.82	SW., 3........	Rain until 10.30, afterward clearing and stars visible till close to horizon. Sheet lightning all around. Light southwesterly swell.
12 mid....	39	48	166	41	28.63	S., 2..........	Clear sky. Sheet lightning all around; lightning in NE. WNW. swell.
Mar. 30:							
4 a. m....	40	1	167	23	28.49	NW., 3........	Clear till 6.30, then overcast. Some rain.
5 a. m....	......	......	......	......	28.47	NW., 4........	Wind rising fast after 6 o'clock. Thick rain. Very low visibility.
8 a. m....	40	7	168	4	28.66	NNW., 8–9....	Gale. Sky overcast, heavy showers; squally after 11 o'clock. Visibility better.
12 noon...	40	13	168	16	29.00	WNW., 10–11.	Squally with hail and rain.

The report continues to noon of April 1, the gale gradually abating. It is interesting to note that during the storm Captain Van Ronkel was in radio communication with the steamships *City of Victoria*, *Canadian Winner*, and *Shabonee*. The first-named vessel reported a barometer reading of 28.14 inches between 2 and 6 p. m. on March 30 in 42° 7′ N., 172° 44′ E.

Pressure at Midway Island was above normal during the first decade and below normal thereafter. The highest pressure recorded was 30.24 inches on the 8th, the lowest 29.76 inches on the 29th. At Honolulu pressure was above normal during the first and third decade and below during the second. The departures were not pronounced. Conditions at Dutch Harbor have already been described.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—The general rainfall for March, expressed as a percentage of the average was: England and Wales, 103; Scotland, 76; Ireland, 72; British Isles, 86.

In London (Camden Square) the mean temperature for March was 41.8° F., or 0.3° F. below the average; the duration of rainfall, 42.2 hours, and the evaporation 0.96 inch.[1]

France.—Paris, March 9.—Nearly all France has suffered heavily from the unusually violent storm which began three days ago, causing heavy material damage

[1] Meteorological Magazine, April, 1922.

and considerable loss of life. It was particularly severe in the northern Departments, whence come reports of numbers of persons killed and injured. Telegraph and telephone lines were blown down, cutting communications generally. The storm off the coast stopped virtually all marine traffic * * *.—*Brooklyn Eagle, March 9, 1922.*

Paris, March 23.—On the second day of spring surface transportation in Paris was demoralized by a small blizzard worse than any seen during the winter, and all France is white with an unusual snow.—*Brooklyn Eagle, March 23, 1922.*

Switzerland.—Geneva, March 15.—Winter in the Swiss Alps has been so severe that scores of wild boars, wolves, and other animals have been driven to the towns and lowlands in search of food * * *.—*New York Evening Mail, March 15, 1922.*

Italy.—Venice, March 23.—A Central News dispatch from Venice says that a tidal wave late last night inundated the city, the water rising to a depth of more than 3 feet in some of the public squares.—*Washington Post, March 24, 1922.*

Genoa, March 25.—The tidal wave which the past few days has swept the Adriatic shores of Italy to-day shifted to the Mediterranean side and extended throughout the Italian Riviera. Many of the railroads and streets of Genoa were inundated, forcing traffic to deviate in order to reach the center of the city. Ships anchored at various places along the coast suffered damage.—*Associated Press.*

Arabia.—Aden.—It is stated in the *Times* on March 28 that unusually heavy rains have filled all but one of the historic reservoirs of Aden.[1]

Africa.—Tetuan, Morocco, March 24.—A severe snowstorm and intense cold has interrupted the movements of the Spanish troops in this vicinity. Communications with the outlying posts have been cut, as the hills surrounding the city are covered with a thick layer of snow.—*Washington Post, March 24, 1922.*

Lourenco, Portuguese East Africa, March 4.—Serious loss of life and damage to property was caused by a tornado which recently swept the seaport town of Chinde, in this territory, destroying the Government office and many other buildings and causing the sinking of numerous launches and other craft in the port * * *.—*Washington Star, March 5, 1922.*

Japan.—Tokio, March 1.—Tokio to-day was in the grip of a severe cold wave and snowstorm, according to dispatches * * *.—*United Press, March 1, 1922.*

Hawaii.—Honolulu, March 19.—Semitorrential rains which have visited the Hawaiian Islands during the past week caused much damage and marooned many tourists and sightseers * * *. Extremely rough weather accompanied the rain, interisland vessel captains reporting the hardest voyages in years.—*Washington Evening Star, March 19, 1922.*

Brazil.—There were destructive floods in the States of Rio de Janiero and Sao Paulo. * * * While in the northeast the cotton crop is suffering from lack of rain, the rice crop in the South is being damaged by abnormally heavy precipitation.[1]

[1] Meteorological Magazine, April, 1922.

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

The outstanding feature of the month was perhaps the excess of rainfall as shown in detail on the inset of Chart V. Heavy rains in March are due to the course taken by cyclonic systems of wind circulation which cross the United States.

During the current month these systems moved from Texas northeastward, crossing the Mississippi in the vicinity of Cairo, Ill., moving thence up the Ohio Valley, and then passing almost directly eastward to the coast. By a movement such as described these storms cross successively the western tributaries of the Mississippi, south of the Missouri, and thus precipitate a large quantity of water in the several basins so crossed. Continuing up the Ohio Valley, the river of the same name must also reach flood stage. While the quantity of water contributed by the storms of the current month was not in itself sufficient to produce a large flood, it doubtless laid the foundation for the great flood which, at this writing (May 1), is passing down the lower Mississippi.

Another exceptional feature of the weather was the high mean pressure over the outlet through which pass the great majority of storms which traverse the United States, viz, New England and the St. Lawrence Valley. Reference to the inset of Chart II, shows the extent to which pressure was above the mean in that locality. This excess was due to the fact that more than the usual number of anticyclones passed over the region in question, which may be simply another way of expressing the belief that the flow of polar air equatorward, for some reason, followed the Hudson Bay-Halifax route.

East of the Rocky Mountains the month was warm and wet; to the westward it was cold and relatively dry.

The usual details follow.

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

The month was unusually active, both HIGHS and LOW exceeding the normal. Most of the important storms began as secondary developments over the southern slope of the Rockies or in the Great Basin and moved east-northeast to pass off the north Atlantic coast. High-pressure areas were not so strong as during the preceding month and few important ones were charted south of Canada, but the total number charted was the same in each case.

LOWS.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
March, 1922	6.0	6.0	1.0	......	7.0	......	......	3.0	1.0	24.0
Average number, 1892-1912, inclusive	3.6	2.1	1.1	0.3	1.9	1.3	0.4	0.3	0.7	11.8

HIGHS.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
March, 1922	5.0	3.0	5.0	....	1.0	14.0
Average number, 1892-1912, inclusive	0.9	0.7	5.6	0.9	0.5	8.5

FREE-AIR CONDITIONS.

By W. R. GREGG, Meteorologist.

As indicated in Tables 1 and 2, free-air conditions at all six kite stations and at all altitudes were, for the month

as a whole, not far from normal. Temperatures were slightly below at and near the surface and slightly above in the higher levels.[1] Comparatively low temperatures were general from the 1st to 3d and from the 19th to 21st (later in each case at eastern than at western stations) in connection with northerly winds between a well-developed cyclone and a following anticyclone. The lowest temperature recorded was −21.7° C. at an altitude of 5,500 meters at Ellendale on the 9th.

Relative humidity was, in general, slightly above normal at all levels except near the surface at Groesbeck. Very low humidities in the upper levels were observed at all stations on the 3d to 4th, 11th to 12th, and 15th to 17th. Vapor pressure departures from normal were similar to those of temperature, with, however, a somewhat larger positive tendency, owing to the excess in relative humidity values.

Resultant winds were about normal, except near the surface at northern stations, where an east component predominated. In the higher levels they were WSW. for the most part. Wind speeds were slightly above normal at Groesbeck and slightly below at other stations. Unusually high winds were observed as follows:

[By means of kites.]

Station.	Date.	Direction.	Velocity.	Altitude.
			m. p. s.	*Meters.*
Drexel, Nebr	22	ssw	32	1,000
Groesbeck, Tex	2	wsw	31	3,800
Do	9	ssw	30	2,900
Do	10	wnw	32	1,800
Do	13	sse	31	1,600
Do	19	nw	34	1,600
Do	31	wnw	31	3,300
Royal Center, Ind	6	sw	37	1,200
Do	11	nne	31	1,700
Do	13	ssw	30	2,700
Do	15	nnw	40	3,200
Do	18	ese	31	600
Do	19	se	38	1,800
Do	23	w	34	1,900
Do	25	wsw	34	1,900

[By means of pilot balloons.]

Station.	Date.	Direction.	Velocity.	Altitude.
Aberdeen Proving Ground, Md	16	nw	47	4,800
Do	18	nnw	34	3,500
Bolling Field, D. C	3	w	31	4,500
Do	16	nw	30	2,500
Broken Arrow, Okla	3	ne	35	7,100
Do	6	w	35	2,400
Do	20	nw	39	4,800
Burlington, Vt	14	w	34	3,000
Camp Benning, Ga	7	w	35	2,500
Do	8	w	42	6,400
Do	11	w	30	3,000
Do	17	nw	35	6,300
Camp Bragg, N. C	7	wnw	33	2,500
Denver, Colo	12	sw	33	5,100
Drexel, Nebr	22	sw	31	1,800
Due West, S. C	8	nw	35	4,800
Do	15	wsw	32	3,500
Do	16	nw	30	8,500
Do	21	w	32	4,200
Do	31	sw	35	3,200
Edgewood Arsenal, Md	3	w	33	4,500
Do	17	nw	39	3,300
Ellendale, N. Dak	7	nne	30	8,200
Do	13	w	36	3,600
Do	14	w	40	7,100
Do	15	wnw	31	7,100
Ellington Field, Tex	10	wnw	45	1,700
Do	14	wnw	42	1,200
Groesbeck, Tex	7	wnw	37	3,900
Do	14	w	32	3,300
Do	15	wnw	35	10,400
Kelly Field, Tex	2	wsw	31	4,000
Key West, Fla	2	nw	37	13,000
Lansing, Mich	2	wsw	33	10,500
Do	8	w	32	5,800
Do	15	wnw	36	4,600
Do	18	nw	36	6,500
Do	29	wsw	32	5,700
Lee Hall, Va	9	w	40	7,600
Madison, Wis	13	w	30	3,100
Do	15	wnw	33	4,600

[1] In Chart IV (climatological) it is shown that surface temperatures were somewhat above normal over most of the region in which kite stations are located. A similar discrepancy was noted in January and its explanation was briefly discussed in the Mo. WEATHER REV. for that month, p. 34.

[By means of pilot balloons.]

Station.	Date.	Direction.	Velocity.	Altitude.
McCook Field, Ohio	3	sw	38	11,700
Do	30	sw	34	2,000
Mitchel Field, N. Y	3	w	33	4,200
Do	16	nw	34	3,000
Do	29	w	36	4,200
Rockwell Field, Calif	12	n	40	4,800
Ross Field, Calif	8	n	36	2,500
Do	17	nnw	31	4,900
Royal Center, Ind	3	ne	34	7,300
Do	4	nne	35	6,900
San Diego, Calif	1	nw	32	3,500
San Francisco, Calif	29	nw	33	4,200

With the passing of winter conditions and the accompanying diminution in the poleward temperature gradient, the frequency of free-air easterly winds shows a very considerable increase. It will be recalled that on February 28 (see discussion in MONTHLY WEATHER REVIEW for that month, pp. 101–102) easterly winds in the upper levels were quite general over the north-central and western portions of the country. This condition not only continued but intensified, being particularly pronounced on March 3, when, as shown in the table of maximum winds above given, northeasterly winds exceeding 30 m. p. s. were observed at 7 to 8 kilometers above Broken Arrow and Royal Center. At other places easterly winds of less speed, but nevertheless fairly strong, occurred on the 3d, as follows: Drexel, N. to NE. at 3 to 5 kilometers; Ithaca, NNE. at 3 to 8 kilometers; Lansing, NNE. to ENE. at 2 to 10 kilometers, increasing considerably in speed with altitude; Madison, SE. at 2 to 3 kilometers and NE. at 4 to 11 kilometers, with speed above 15 m. p. s. in highest levels; and Scott Field, (Belleville, Ill.), NE. to ENE. at 2 to 4 kilometers. In practically all of these cases winds with a west component prevailed at and near the surface, in conformity with the sea-level pressure conditions shown on the weather map of that day. High pressure was central over Texas and low pressure north of the Dakotas. The significant feature of the map, however, is the entire absence of any poleward temperature gradient. On the other hand, the weather was somewhat colder in northern Texas than it was in northern Montana. Moreover, this atitudinal reversal in temperature was greater in the free air than at the surface, as shown in the following table:

Altitude, m. s. l.	Ellendale, N. Dak.	Groesbeck, Tex.
Meters.	°*C.*	°*C.*
1,000	6.2	−4.8
2,000	5.0	−1.8
3,000	1.6	−5.6

The reversal in free-air pressure gradients and the resulting easterly winds above westerly winds are thus easily accounted for. It is uncertain to what height this reversal extended, since easterly winds persisted to the greatest heights reached—about 11 or 12 kilometers. However, much the same, though somewhat less pronounced, condition prevailed on the 1st and 2d, and one observation on the former date, at Ellendale, showed the easterly wind ceasing at 12 kilometers. Above this level the direction was NNW. up to 19 kilometers, the highest altitude reached. At 9 to 10 kilometers the NE. wind had a speed of about 15 m. p. s. With the change to NNW. the speed diminished to about 6 m. p. s., but again increased to 10 or 12 at 18 and 19 kilometers.

Free-air easterly winds continued at Lansing and Royal Center on the 4th, but of greatly diminished speed.

Easterly winds at moderate altitudes prevailed quite generally also from the 9th to 12th and from the 14th to 17th (later at eastern than at western stations) in connection with well-developed cyclones which moved from Texas east-northeastward to the Atlantic coast. In neither case, however, were the winds as strong nor did they extend to as great altitudes as those from February 28 to March 4.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1922.*

TEMPERATURE (°C.).

Altitude. m. s. l. (*m.*)	Broken Arrow, Okla. (233*m.*). Mean.	Broken Arrow Departure from normal.	Drexel, Nebr. (396*m.*). Mean.	Drexel Departure from normal.	Due West, S. C. (217*m.*). Mean.	Due West Departure from normal.	Ellendale, N. Dak. (444*m.*). Mean.	Ellendale Departure from normal.	Groesbeck, Tex. (141*m.*). Mean.	Groesbeck Departure from normal.	Royal Center, Ind. (225*m.*). Mean.	Royal Center Departure from normal.
Surface	10.4	−0.8	1.9	−2.4	13.2		−2.3	0.0	12.1	−2.1	5.7	−0.4
250	10.2	−0.9			12.9				11.7	−1.9	5.6	−0.2
500	8.0	−1.3	1.4	−2.3	10.7		−2.4	0.0	10.6	−1.7	4.3	+0.4
750	6.5	−1.6	0.9	−1.8	9.0		−2.6	0.0	9.3	−1.9	3.5	+0.6
1,000	6.1	−1.2	0.9	−1.3	7.9		−2.8	−0.3	8.7	−1.6	3.5	+1.3
1,250	5.8	−1.0	1.3	−0.9	6.9		−2.7	+0.1	8.2	−1.4	3.4	+1.7
1,500	5.2	−1.0	1.4	−0.5	6.0		−2.9	+0.4	7.7	−1.2	2.5	+1.6
2,000	3.7	−0.8	−0.4	−0.5	3.9		−4.4	+0.6	6.8	−0.7	0.9	+1.6
2,500	1.5	−0.7	−2.7	−0.3	1.8		−6.0	+1.2	4.9	−0.3	−1.1	+1.7
3,000	−1.1	−0.7	−4.8	+0.3	0.1		−8.3	+1.4	2.4	−0.3	−2.7	+2.4
3,500	−3.8	−0.8	−7.2	+0.7	−2.6		−10.6	+1.6	−0.6	−0.4		
4,000	−7.2	−0.5	−9.5	+1.1	−5.2		−12.6	+2.1	−3.4	−0.3		
4,500	−10.7	−0.4					−15.4	+2.6	−6.2	−0.7		
5,000							−18.6	+2.6	−9.1	−1.1		

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1922*—Continued.

RELATIVE HUMIDITY (%).

Altitude. m. s. l. (*m.*)	Broken Arrow, Okla. (233*m.*). Mean.	Broken Arrow Departure from normal.	Drexel, Nebr. (396*m.*). Mean.	Drexel Departure from normal.	Due West, S. C. (217*m.*). Mean.	Due West Departure from normal.	Ellendale, N. Dak. (444*m.*). Mean.	Ellendale Departure from normal.	Groesbeck Tex. (141*m.*). Mean.	Groesbeck Departure from normal.	Royal Center, Ind. (225*m.*). Mean.	Royal Center Departure from normal.
Surface	67	0	77	+10	68		82	+6	69	−2	77	+6
250	67	0			68				67	−3	76	+5
500	69	+3	76	+10	69		80	+6	64	−3	73	+4
750	69	+5	73	+ 9	69		71	+4	64	0	71	+5
1,000	65	+3	67	+ 7	69		65	+3	61	0	66	+3
1,250	59	+1	57	+ 3	69		58	+1	58	+ 2	62	+2
1,500	54	0	51	+ 1	68		53	−1	54	+ 3	62	+3
2,000	45	−1	48	0	62		56	+3	47	+ 8	63	+6
2,500	42	−1	50	+ 2	53		57	+3	41	+ 7	65	+9
3,000	38	0	50	0	47		56	+2	36	+ 6	62	+5
3,500	36	0	49	0	53		61	+7	37	+ 7		
4,000	35	+1	49	0	54		58	+2	40	+ 9		
4,500	34	0					58	+1	45	+12		
5,000							67	+8	40	+ 9		

VAPOR PRESSURE (*mb.*).

Altitude. m. s. l. (*m.*)	Broken Arrow Mean.	Broken Arrow Departure from normal.	Drexel Mean.	Drexel Departure from normal.	Due West Mean.	Due West Departure from normal.	Ellendale Mean.	Ellendale Departure from normal.	Groesbeck Mean.	Groesbeck Departure from normal.	Royal Center Mean.	Royal Center Departure from normal.
Surface	8.77	−0.74	5.50	+0.04	10.88		4.29	+0.17	10.41	−1.81	7.13	+0.02
250	8.71	−0.72			10.74				9.93	−1.74	6.97	+0.00
500	7.75	−0.65	5.27	+0.03	9.63		4.12	+0.12	8.78	−1.57	6.11	+0.12
750	6.94	−0.62	4.76	+0.07	8.72		3.47	−0.03	8.16	−1.17	5.65	+0.26
1,000	6.23	−0.66	4.31	+0.11	7.83		3.06	−0.18	7.48	−0.82	5.14	+0.27
1,250	5.51	−0.75	3.72	−0.04	7.36		2.76	−0.27	6.87	−0.39	4.78	+0.33
1,500	4.81	−0.73	3.35	−0.03	6.61		2.56	−0.26	6.06	−0.12	4.39	+0.27
2,000	3.64	−0.61	2.85	+0.02	5.17		2.50	+0.08	4.90	+0.77	3.95	+0.45
2,500	2.96	−0.48	2.60	+0.20	3.73		2.13	+0.09	3.64	+0.72	3.65	+0.62
3,000	2.35	−0.35	2.25	+0.21	2.78		1.60	−0.03	2.81	+0.64	3.32	+0.58
3,500	2.12	−0.22	1.79	+0.12	2.64		1.47	+0.14	2.45	+0.58		
4,000	1.91	−0.05	1.67	+0.20	2.06		1.28	+0.20	2.31	+0.57		
4,500	1.77	+0.05					1.14	+0.30	2.20	+0.54		
5,000							1.06	+0.41	1.79	+0.31		

TABLE 2.—*Free-air resultant winds (m. p. s.) during March, 1922.*

Altitude. m. s. l. (*m*).	Broken Arrow, Okla. (233*m.*). Mean. Dir.	Mean. Vel.	Normal. Dir.	Normal. Vel.	Drexel, Nebr. (396*m.*). Mean. Dir.	Mean. Vel.	Normal. Dir.	Normal. Vel.	Due West, S. C. (217*m.*). Mean. Dir.	Mean. Vel.
Surface	S. 3° E.	2.6	S. 1° E.	3.2	N. 74° E.	0.2	S. 38° W.	0.9	S. 57° W.	3.2
250	S. 3° E.	2.6	S. 1° E.	3.4					S. 55° W.	3.3
500	S. 2° W.	3.8	S. 6° W.	5.2	S. 41° E.	0.7	S. 38° W.	1.1	S. 52° W.	3.8
750	S. 5° W.	4.6	S. 9° W.	6.7	S. 9° E.	1.5	S. 63° W.	2.2	S. 53° W.	4.6
1,000	S. 17° W.	5.4	S. 21° W.	7.6	S. 38° W.	1.3	S. 75° W.	3.0	S. 47° W.	5.6
1,250	S. 39° W.	5.9	S. 31° W.	8.2	S. 76° W.	1.6	S. 87° W.	3.8	S. 55° W.	7.0
1,500	S. 47° W.	7.1	S. 48° W.	7.1	N. 82° W.	2.5	S. 87° W.	4.9	S. 58° W.	9.1
2,000	S. 52° W.	8.1	S. 62° W.	6.9	S. 86° W.	2.9	S. 88° W.	6.6	S. 66° W.	11.9
2,500	S. 64° W.	9.0	S. 67° W.	8.0	S. 82° W.	1.9	S. 86° W.	8.3	S. 83° W.	13.1
3,000	W.	8.2	S. 79° W.	8.7	S. 64° W.	3.6	S. 86° W.	10.6	S. 88° W.	13.0
3,500	S. 76° W.	11.5	S. 69° W.	11.4	S. 72° W.	3.3	N. 86° W.	14.1	S. 80° W.	10.6
4,000	S. 68° W.	11.5	S. 77° W.	13.2	N. 35° E.	8.7	N. 79° W.	16.6	S. 83° W.	12.4
4,500	S. 45° W.	11.5	S. 70° W.	11.5					S. 67° W.	23.0
5,000	S. 45° W.	11.5	S. 71° W.	12.5						

Altitude. m. s. l. (*m*).	Ellendale, N. Dak. (444*m.*). Mean. Dir.	Mean. Vel.	Normal. Dir.	Normal. Vel.	Groesbeck, Tex. (141*m.*). Mean. Dir.	Mean. Vel.	Normal. Dir.	Normal. Vel.	Royal Center, Ind. (225*m.*). Mean. Dir.	Mean. Vel.	Normal. Dir.	Normal. Vel.
Surface	N. 37° E.	0.9	N. 48° W.	1.5	S. 59° W.	2.0	S. 5° W.	1.6	S. 60° E.	3.0	S. 24° W.	2.0
250					S. 44° W.	2.6	S. 1° W.	2.5	S. 55° E.	3.3	S. 23° W.	2.2
500	N. 42° E.	0.7	N. 59° W.	1.4	S. 49° W.	5.3	S. 10° W.	4.7	S. 22° E.	5.8	S. 37° W.	4.8
750	N. 15° E.	0.3	S. 85° W.	2.1	S. 56° W.	6.4	S. 23° W.	5.4	S. 19° E.	7.5	S. 42° W.	6.2
1,000	S. 27° W.	1.2	S. 80° W.	2.7	S. 63° W.	6.8	S. 33° W.	6.1	S.	5.1	S. 51° W.	6.4
1,250	S. 62° W.	1.4	S. 89° W.	3.6	S. 68° W.	7.6	S. 40° W.	6.4	S. 3° W.	4.7	S. 59° W.	7.5
1,500	S. 51° W.	2.3	W.	5.0	S. 77° W.	7.7	S. 46° W.	6.5	S. 14° W.	5.3	S. 61° W.	8.5
2,000	S. 57° W.	5.0	N. 88° W.	7.4	S. 86° W.	10.4	S. 50° W.	7.6	S. 36° W.	7.5	S. 68° W.	10.2
2,500	S. 66° W.	6.2	N. 83° W.	10.1	S. 77° W.	11.0	S. 63° W.	9.4	S. 69° W.	8.8	S. 77° W.	11.0
3,000	S. 78° W.	8.3	N. 80° W.	11.1	S. 66° W.	9.8	S. 67° W.	9.2	N. 89° W.	10.7	S. 83° W.	13.4
3,500	S. 78° W.	12.5	N. 86° W.	12.8	S. 80° W.	12.2	S. 76° W.	11.8	N. 22° W.	32.2	S. 78° W.	15.5
4,000	S. 65° W.	12.5	S. 89° W.	15.2	S. 68° W.	14.4	S. 69° W.	13.6				
4,500	S. 64° W.	13.9	S. 86° W.	16.1	S. 72° W.	11.8	S. 85° W.	13.1				
5,000	S. 68° W.	13.8	N. 87° W.	17.4	S. 62° W.	17.0	S. 84° W.	16.2				

THE WEATHER ELEMENTS.

By P. C. Day, Climatologist and Chief of Division.

PRESSURE AND WINDS.

The atmospheric circulation during March, 1922, like the preceding month, was unusually active, and cyclones, having their origin mostly over the Southwest, moved in rapid succession over the central valleys and eastern districts.

Storms of this character gave important precipitation during the following periods: On the 1st and 2d, from eastern Texas, Oklahoma, and Kansas to the middle Atlantic coast, the falls being particularly heavy in portions of the Gulf States and over most drainage areas of the southern tributaries of the Ohio; from the 13th to 15th, when another low area moved from central Texas slightly northeastward to the middle Atlantic coast, and heavy rains again fell over much of the area covered by the storm first referred to, extending somewhat farther north, however, into the lower Missouri Valley; again from the 18th to 21st, a storm of wide extent, moving eastward somewhat north of the courses pursued by those noted earlier in the month, gave general precipitation over nearly all portions of the country from the Rocky Mountains eastward, heavy rain again falling over the Ohio and middle Mississippi watersheds and extending into the Gulf and Atlantic Coast States and over the Great Lakes. A fourth important rain area having centers of low pressure over Texas and in the valley of the Red River of the North, appeared on the morning of the 25th, and during the remainder of the month rains were frequent over extensive areas from the Great Plains eastward, the falls being particularly heavy in the watersheds of the Ohio and Mississippi Rivers, and over portions of the Gulf States; at Houston, Tex., more than 8 inches occurred from the 24th to 26th.

Anticyclones were usually not so well developed as the cyclones, and passed eastward, as a rule, near the northern border, their influence being most pronounced over the region from the Great Lakes eastward and southeastward.

For the month as a whole, pressure was highest over the Great Lakes and Atlantic Coast States, and lowest in the southern Rocky Mountains and adjacent regions. It was below normal from the middle Plains region northward into the Canadian Provinces, but elsewhere throughout the United States and Canada the average pressure was above normal.

As compared with February just passed, the average pressure was decidedly lower over the great central valleys and in the British northwest.

It was slightly higher than last month over a small area in the Great Lakes region and along the immediate Pacific coast.

Local high winds were of frequent occurrence, as may usually be expected in March, and a number of lives were lost and considerable property damage resulted. The most important periods of damaging winds were on the 13th and 14th, when severe storms of tornadic character swept over portions of Arkansas, Louisiana, Mississippi, Oklahoma, and Tennessee, causing the loss of about 25 lives, injury to about 100, and large property damage; and on the 30th and 31st, when high winds prevailed over extensive areas in the Ohio Valley and Gulf States.

As is usual in March, the prevailing winds varied greatly. They were usually from northerly points over the Great Lakes and to the eastward, from southerly points in the Gulf States and great central valleys and variable elsewhere.

TEMPERATURE.

No important sudden changes of temperature occurred during the month and the daily departures from normal were usually moderate, save for the first few days in portions of the Southwest. On the whole, cool weather continued in the more western districts, particularly during the first half of the month, a condition that has persisted, more or less, in that region since the beginning of the year. On the other hand, generally moderate temperatures persisted in the districts from the Rocky Mountains eastward.

The highest temperatures of the month were usually recorded during the latter half. A warm period, beginning on the Pacific coast about the 20th, gradually moved eastward, reaching in succession the Plains States by the 22d to 23d, the central valleys by the 24th, most eastern districts by the 26th, and the more southern States toward the end of the month. No unusually high temperatures were reported during the month, the maximum observed, 100°, occurring in Texas on the 13th.

The month opened with cold weather prevailing in Texas and portions of adjacent States, the temperature having fallen to or below freezing as far south as Corpus Christi, and the lowest temperatures ever observed in March were reported at a number of points in the southern Plains and adjacent portions of the western mountain regions. The 1st was the coldest day of the month in nearly all districts from the Great Plains westward. the 2d and 3d were the coldest in portions of the central valleys, and the 4th and 5th over the Southern States from Texas eastward. Over the Middle Atlantic States and New England the coldest period of the month was on the 1st and 2d.

Minimum temperatures were below zero in all the western Mountain States and along the entire northern border; the lowest observed, −43°, occurred in the mountains of Wyoming. Temperatures below freezing were reported from some portion of all the States.

For the month, as a whole, the temperature averaged below normal over all districts from the Rocky Mountains westward and in portions of the West Gulf States. Over the districts to the eastward, the temperature averages were mainly above normal, the month being distinctly warm in the upper Mississippi and lower Missouri valleys and thence northward into Canada, where locally the averages were 10° or more above normal.

PRECIPITATION.

In the central valleys and eastern districts, March was generally rainy, the total falls for the month being in excess of the normal over all States from the Great Plains eastward to the Atlantic coast, save in Maine, Florida, and the two Dakotas. In portions of the Ohio and middle Mississippi valleys and generally over the Gulf States, the precipitation was far in excess of the normal, and in some States and sections the fall was the greatest of record for March. In portions of Arizona, Colorado, and generally in the far Northwest, the monthly precipitation was likewise in excess of the normal, but usually to a much less extent.

From the Dakotas southwestward to and including California the month was drier than usual, and similar conditions existed in the Florida peninsula. Monthly amounts in excess of 10 inches were reported from portions of all the Gulf and South Atlantic States and from Kansas and Oklahoma to the States of the Ohio Valley. Amounts from 10 to 15 inches were likewise reported from exposed points in the mountains of the Pacific Coast States.

The heaviest fall for the month, 17 inches, was reported from central Texas, while in the western part of that State there was little or no precipitation. Likewise in California no precipitation occurred over a considerable area in the southeastern part of the State, while in the northern mountain districts amounts in excess of 15 inches were recorded.

SNOWFALL.

The distribution of the monthly snowfall is shown on Chart VIII of this REVIEW. In general, snow was widely distributed, only the more southern districts having none, and at some southern stations it was observed the first time in March for many years.

Fairly heavy falls were received in the upper portions of the Ohio drainage area, and portions of New York and New England had totals for the month of 10 to 15 inches or more. Over most of the interior portions of the country, including the Great Lakes region, the snowfall was mainly less than normal, and that which fell soon melted.

In the western mountain districts the snowfall was mainly near the normal amounts, and on account of continued cool weather there was less melting than usual. As a result the prospects continue good for a plentiful supply of water in most districts where the accumulated snow furnishes the major portion of water required for irrigation and other purposes.

At the end of the month little snow remained on the ground save in northern New York, portions of New England, the region of the Great Lakes, and in the mountain districts of the West.

RELATIVE HUMIDITY.

Like the precipitation, the average relative humidity was generally above normal over the districts from the Rocky Mountains eastward, although in the Appalachian Mountain region and portions of the North Atlantic Coast States there were local deficiencies of considerable degree, and there were also well-marked deficiencies in portions of Texas.

From the Rocky Mountains westward the relative humidity was mainly deficient, but here, too, there were localities having values decidedly in excess of the normal.

Severe local storms.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
Augusta, Ga. (near)	7	A. m.		6		Wind and rain	Severe general damage. Many persons injured.	The Piedmont (Greenville, S. C.).
Evansdale, N. C.	7	A. m.	300 yards to one-half mile.	1	$40,000-50,000	Tornado	Houses, barns, and other buildings razed; 15 or more persons injured.	Raleigh Times (N. C.).
New York, N. Y.	7	P. m.				Gale	Minor accidents in harbor. Wind velocity, 70 miles.	New York Times. Official U. S. Weather Bureau.
Northern Louisiana	10	A. m.				Wind and rain	Damage confined largely to timber. Some property damage.	Shreveport Times (La.).
Louisiana, Arkansas, Mississippi, and Oklahoma.	13-14			25		Tornadoes and cyclones.	About 100 persons injured and a loss in property damage estimated at thousands of dollars.	New York Herald; Indianapolis Star (Ind.); Commercial Appeal (Tenn.).
Mobile and Cullman Counties, Ala.	14					Tornado	Several injured and much property lost	Official U. S. Weather Bureau.
Giles County, Tenn	14	P. m.			15,000	do	60 buildings damaged and some stock killed; 10 persons injured.	Do.
Petersburg, Tenn	14	P. m.				Wind	School and small buildings damaged	Do.
Clarksville, Tenn	14					Hail	Greenhouses damaged	Do.
Santa Fe, N. Mex	17					Wind	Severe storm over much of Rio Grande Valley. Some damage to buildings.	Do.
Telluride, Colo	17-19					Snow	Wire communication crippled, railroad traffic delayed, roads blocked.	Daily Sentinel (Grand Junction, Colo.).
Laurel and Brookhaven, Miss.	20	A. m.		1		Tornado	Considerable damage to property and some live stock killed. Several persons injured.	Pensacola Journal (Fla.).
Lee County, Ala	20			2		do	Heavy property losses	Do.
Bull Run, Oreg	21	A. m.				Wind and rain	Street-car service discontinued; power service handicapped.	Journal (Portland, Oreg.).
Beaumont, Tex., and vicinity	25	P. m.		3	100,000	Tornado	Damage to property and scores injured	Dallas Morning News (Tex.).
Southern Indiana	29-30					Cyclone	Buildings unroofed and demolished. Telegraph and telephone lines damaged severely.	Evansville Courier (Ind.).
Shreveport, La. (40 miles south of).	30	P. m.			100,000	Wind	140 derricks of the Red River Parish oil field and several buildings wrecked.	Chattanooga Times (Tenn.). Official U. S. Weather Bureau.
Savannah, Tenn	30					do	2 injured and a number of homes and cotton gin damaged.	Chattanooga Times (Tenn.).
Columbus, Ohio, and vicinity	30			1		do	Considerable property loss. Telephone and telegraph poles blown down. Trees uprooted, etc.	Evansville Courier (Ind.). Official U. S. Weather Bureau.
Cincinnati, Ohio	30	P. m.				do	General damage done	Do.
Southern Michigan	30-31					Ice	Heavy damage sustained by telegraph, telephone, and light companies. Car service interrupted; trees down. Damage estimated at several million dollars.	Official U. S. Weather Bureau (Detroit). Free Press (Detroit, Mich.).
Cullman and Lawrence Counties, Ala.	31		50-1,760			Tornado	Several persons injured; 15 residences and 2 business houses damaged. Wire communication interrupted.	Chattanooga Times (Tenn.). Official U. S. Weather Bureau.
Huntsville, Ala. (southwest of).	31	A. m.				do	3 persons injured, 3 houses blown away, power lines down. Northern Alabama towns in darkness for 9 hours.	Chattanooga Times (Tenn.).
Bradley County, Tenn	31	A. m.				do	General damage done	Do.

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

A disturbance of moderate intensity was centered near Cape Hatteras on the morning of the 4th. Northeast storm warnings were ordered displayed at 9 a. m. from Norfolk, Va., to Eastport, Me., in the expectation that there would be a marked increase in the storm's intensity. A velocity of 56 miles an hour from the east was reached at Atlantic City, N. J., and 72 miles from the northwest at New York City.

At 8 p. m. of the 6th a storm of marked strength was central over Lake Superior, moving northeastward, and pressure was decreasing rapidly from the lower Lake region southward to the east Gulf coast. Southwest warnings were displayed at 10 p. m. from Jacksonville, Fla., to Eastport, Me. Practically every station north of Savannah, Ga., reported a verifying velocity, the highest being 72 miles an hour from the south at New York City.

Southeast warnings were displayed from Bay St. Louis, Miss., to Cedar Keys, Fla., on the 9th and from Deleware Breakwater to Eastport, Me., on the 10th in connection with the northeastward movement of a disturbance from Texas to the southern New England coast. Pensacola, Fla., reported a maximum velocity of 44 miles an hour from the southwest and Nantucket, Mass., and Block Island, R. I., each 48 miles an hour from the northeast.

On the morning of the 15th a disturbance of considerable intensity was central over western North Carolina, moving rapidly eastward. Northeast storm warnings were ordered displayed from Norfolk, Va., to Atlantic City, N. J., and northwest warnings south of Norfolk to Cape Hatteras. These warnings were well verified, Cape Henry, Va., reporting a maximum velocity of 60 miles an hour from the northeast.

At noon of the 19th a disturbance of marked intensity and wide extent was central over Illinois, moving northeastward. Southwest warnings were displayed from Jacksonville, Fla., to Delaware Breakwater at 4 p. m., and southeast warnings from Baltimore, Md., to Eastport, Me., at 10 p. m. Verifying velocities were reached at a number of stations.

A disturbance that was over the west Gulf States on the 30th, moved rapidly northeastward to the southern New England coast during the next two days, attended by shifting gales along the Middle Atlantic and North Atlantic coasts. Warnings were displayed well in advance of the storm.

Warnings of strong winds were sent to open ports on Lake Michigan on 18 days during the month and warnings of "northers" to the Panama Canal Zone on the 2d and 21st.

Cold-wave warnings were issued for very limited areas on the 1st, 2d, 21st, and 28th, and frost warnings for portions of the Southern States on about one-third of the days of the month.—*Charles L. Mitchell.*

CHICAGO FORECAST DISTRICT.

No special warnings of any kind were necessary in the Chicago Forecast District until the 18th, when advices were sent to the live-stock interests in Nebraska and western Kansas. On that date also heavy snow warnings were issued for northern Wisconsin and eastern Minnesota.

On the 19th, 20th, and 26th, frost warnings were issued for southeastern Kansas and southwestern Missouri, in the latter State the advices being made especially for the benefit of the strawberry growers.

The first severe cold weather of the month appeared in the Canadian Northwest on the morning of March 26. However, no cold-wave warnings were issued then as the temperature in the northern Plains States and the northern Rocky Mountain region was already rather low. On the 27th–28th, cold-wave warnings were ordered for the southern Plains States and the middle and lower Missouri and the middle Mississippi Valleys. The expected drop in temperature was quite pronounced from South Dakota southward over Nebraska and Kansas, but to the eastward the changes were not decided, as the high-pressure area accompanying the cold moved eastward to the Lake region during the 28th. Stock advices were issued for South Dakota, Nebraska, southeastern Wyoming, and western Kansas on the 27th.

Freezing temperature was indicated for southern Missouri and southeastern Illinois on the 31st.

The special forecast service to the *Reporter-Enterprise*, Oconto, Wis., begun in February, was continued during March, a forecast covering Friday, Saturday, and Sunday being telegraphed each Thursday morning. Temperature forecasts for a week in advance were sent to the Wenatchee Valley Traffic Association, Wenatchee, Wash., each Monday, to be used by the association in the protection of their fruit shipments across the northern Rockies and the nothern Plains.—*E. H. Haines.*

NEW ORLEANS FORECAST DISTRICT.

The month opened with cold weather in most sections of the district and below freezing to the middle coast of Texas. Though cold weather continued in Texas and northern Louisiana the arrival of freezing weather on the Louisiana coast was delayed until the 4th, but temperatures were only a few degrees above freezing on the 2d and 3d. On the morning of the 3d the freezing temperature forecast for the Louisiana coast was repeated and a warning of killing frost was added. Steps were taken to protect vegetation, but the less hardy crops suffered where they could not be protected. This cold spell, coming late in the winter, was as severe as any during the winter and the most injurious.

After the 4th, frost or freezing-temperature warnings were issued for portions of the district on the 6th, 7th, 9th, 10th, 15th, 20th, 21st, 25th, 26th, 27th, 28th, and 31st.

Warnings for live-stock interests in northwestern Oklahoma and the Texas panhandle were issued on the 8th. Rather heavy snow occurred in these sections on the 9th, with temperatures below freezing.

The month may be characterized as windy and rainy, due to the frequent occurrence of southwestern LOWS which passed northeastward over the district.

On the 1st a disturbance of moderate intensity was central over southern Mississippi and a large area of high pressure was central over South Dakota. The cold-wave warning issued the preceding day was repeated for southern Louisiana and northwest storm warnings were continued on the east coast of Texas, small-craft warnings being displayed on the west coast of Texas. These warnings were verified.

Small-craft warnings were displayed on the Texas coast on the 8th, 9th, 13th, 25th, 29th, 30th, and 31st, and on the Louisiana coast on the 9th, 13th, and 25th.

The small-craft warnings were changed to storm warnings on the 9th and 13th after the receipt of special midday observations. Winds occurred as forecast.

In addition to the strong winds and moderate gales that occurred with the display of the warnings mentioned, a moderate northwest gale occurred at Galveston during the morning of the 19th. A local storm of more than ordinary intensity occurred on the east coast of Texas in the early morning of the 29th. The weather map of the preceding evening gave no indications of this local squall.—*R. A. Dyke.*

DENVER FORECAST DISTRICT.

An area of low pressure which extended southeastward from British Columbia during the 4th, with a center of marked intensity over eastern Colorado on the morning of the 5th, was attended by light to moderately heavy snows in this State and Utah during the 4th–5th. The remainder of the month was notable because of the unusual number of storms which developed on the middle and southern portions of the Rocky Mountain plateau or which moved southeastward from the north Pacific coast. LOWS of the types referred to advanced across the Denver district on the 7th–8th, 11th–12th, 16th–18th, 22d–24th, 26th–27th, and the 28th–29th, while another disturbance was central over southern Utah on the 31st. The HIGHS as a rule, moved eastward from Oregon, Washington, or northern California.

Moderately heavy snows occurred in western Colorado on the 5th, in northern and eastern New Mexico on the 8th–9th, in northern Utah on the 10th–11th, and in northern Utah and southwestern Colorado on the 28th–29th. Heavy snows fell in northeastern Arizona and southwestern Colorado on the 11th–12th and the 16th–17th.

Warnings of heavy snow and stockmen's warnings were issued on the 11th for western Colorado, northwestern New Mexico, northern Arizona, and southern Utah and were justified, except in northwestern Colorado.

No cold-wave warnings were issued during the month. Moderate cold waves, without warnings, occurred in southwestern Colorado on the 6th, due to an increase in the intensity of a HIGH that was over California on the morning of the 5th, and in northeastern Colorado on the 28th, owing to the very rapid eastward movement of a LOW that was over the eastern portion of this State on the morning of the 27th and to the correspondingly rapid extension southward to Texas of a HIGH whose crest was over southern Saskatchewan on the last-named date. A local cold wave of moderate intensity also occurred at Santa Fe on the 18th.

Warnings of freezing temperature were issued for south-central and southeastern Arizona on the 1st, for southern New Mexico and south-central and southeastern Arizona on the 6th, and for temperatures near freezing in extreme southeastern New Mexico on the 19th and 28th. The warnings were verified, except in south-central and southeastern Arizona on the 7th and in extreme southeastern New Mexico on the 29th.

Frost warnings were issued for extreme southwestern Arizona on the 1st, 2d, 6th, 12th, and 18th and for southern New Mexico on the 25th and extreme southeastern New Mexico on the 19th, 26th, and 30th. These were generally verified by the actual occurrence of frost or temperatures at which frost might be expected, except in the most extreme southwest portion of Arizona on the 7th and 19th and in extreme southeastern New Mexico on the 27th.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT.

In this district the weather during March was much like that of the preceding month, the distinctive feature being the succession of storms moving inland at a latitude lower than usual. Near the coast the storms were less violent than those of February, but radio reports from vessels in the north Pacific showed the prevalence of strong gales in that region during the greater portion of the month.

The temperature was somewhat below normal, but there were no very cold or warm periods in any portion of the district.

There were more than the usual number of rainy days during the month, but the precipitation was nowhere excessive.

Warnings of heavy frost were issued five times in California, and while frosts occurred, they were not of a damaging nature.

Storm warnings were ordered 14 times, as follows: Washington and Oregon coast, 9; northern California coast, 4; southern California coast, 1; small craft, 2; and advisory, 2. The warnings were generally verified, and, judging from radio reports at sea, they are all believed to have been justified.

The many radio reports received from vessels in the north Pacific were of great assistance in keeping the forecaster in touch with approaching weather conditions.—*G. H. Willson.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

The great flood in the extreme lower Ohio and lower Mississippi Rivers was in full progress at the close of the month, and the report thereon will be delayed until the flood has subsided.

Floods over the North Atlantic drainage area.—On March 8 rain, combined with high temperatures, melting snow, and the breaking of an ice gorge in the Connecticut River at White River Junction, Vt., caused a rapid rise to a stage of 16 feet, or 3 feet above the flood stage, by the morning of March 9. It so happened that the gorge broke without starting the ice, so that a warning issued on March 8 for flood stages below failed of verification by several feet. Similar meteorological conditions caused the ice in the upper Susquehanna River to move out on a rapidly rising river, with crests somewhat above the flood stage. The flood lasted but a few hours and the damage was slight.

On March 15 the ice in the White River of Connecticut moved out, causing another rapid rise in the Connecticut River at White River Junction, and at 4 p. m. the stage was 18.2 feet, 5.2 feet above the flood stage. There was not much rise below, and the ice did not begin to move out at Bellows Falls, Vt., until March 25. During the last week of the month moderate rains and high temperatures caused a rapid melting of the snow covering, and the greatest rise of the month set in, the ice also moving out from points above. The crest stages were as follows: White River Junction, Vt., 19.5 feet, 6.5 feet above flood stage, and Bellows Falls, Vt., 10.2 feet, 1.8 feet below flood stage, on March 30; Holyoke, Mass., 8.7 feet, 0.3 foot below flood stage, at midnight March 30–31, and Hartford, Conn., 19.9 feet, 3 feet above flood stage, on March 31. Warning of this flood was issued on March 28.

South Atlantic drainage area.—Heavy rains on March 2 and 3 caused general floods in the rivers of the Carolinas, and general warnings were issued on March 3 for floods in the main streams.

Warnings were issued on March 3, 4, 10, and 11, and were well verified as to flood occurrence, although in several instances crest stages were not quite as high as had been forecast. Although the floods were prolonged by additional heavy rains, the losses as reported in North Carolina totaled only $20,000, while the money value of property saved by the warnings was reported to have been $60,000.

The crest stage at Cheraw, S. C., on the Peedee River, was 33.5 feet, or 6.5 feet above flood stage on March 5. Additional rains in substantial amount on March 6, 7, and 10 again brought the river above flood stage and the floods extended to the Black, Lynches, and Waccamaw Rivers. Warnings were issued promptly for all rivers, and the reported value of property saved thereby was $71,200. Loss and damage reported to $13,000.

The Santee River had been in flood since February 3, so that the only material effect was a prolongation of the flood period, and the river was still above flood stage at the close of the month.

The Catawba River did not reach flood stage, but the Wateree at Camden, S. C., was above the flood stage of 24 feet from March 7 to 9, inclusive, with a crest stage of 27.2 feet on March 8. The Broad and Saluda Rivers were in moderate flood on March 11 and 12, and the Congaree on March 7 and 8, with a crest of 18.8, 3.8 feet above flood stage at Columbia, S. C., on March 7. There was also a second local and moderate flood in the Saluda River at Chappels, S. C., on March 21, when the river gage read 1.5 feet above the flood stage of 14 feet. Warnings were widely distributed whenever necessary. Losses amounting to $6,100 were reported in the swamp regions below Columbia and Camden, S. C., but the section had been in flood so long that very little live stock could enter the swamps. Estimated money value of property saved through warnings, $44,000.

Although flood stages were reached in the upper Savannah River on March 11 and 12, nothing of interest occurred and there was no damage done.

The rainfall was so heavy and the rises in the Oconee and Ocmulgee Rivers of Georgia were so rapid during the night of March 6–7 that it was impossible to issue local flood warnings at Milledgeville and Macon, although ample warnings were given to points below. The 24-hour rain at Milledgeville was 5.50 inches and the rise in the river 20.4 feet, while at Macon they were 6.37 inches and 11 feet, respectively. Another less excessive rain that occurred on March 10 started another rise in both rivers before they had had an opportunity to fall to normal conditions, and another severe flood resulted, for which warnings had previously been issued.

The damage was great. Bridges were washed away, washouts occurred on railroads, and crops and lumber interests suffered severely. It has been impossible to obtain estimates of losses.

The floods in the Apalachicola drainage basin were neither as severe nor as disastrous as in the Altamaha Basin, and the damage was slight. Warnings were issued well in advance of the flood.

The flood in the Pearl River of Mississippi was quite decided and prolonged, although the damage was not extensive, as crops had not yet been planted. The flood began on the last day of February and continued until March 25, with a crest stage of 28.8 feet at Jackson, Miss., or 8.8 feet above flood stage, on March 11. Heavy rains fell on March 30 and 31, and another flood set in during March 31 and continued beyond the first week of April, with a crest stage at Jackson of 27.6 feet on April 6.

Warnings were issued frequently and the total losses reported amounted to $8,500. The value of property saved through the warnings was about $11,000. There were no other floods of consequence in the Pascagoula system.

There were moderate floods in the lower Black Warrior and lower Tombigbee Rivers early in the month and again about the middle of the month, for both of which timely warnings were issued. At Demopolis, Ala., the overflow continued for about three weeks from March 4, with a crest stage of 56.5 feet, 17.5 feet above flood stage, on March 19 and 20. The crest stage at Tuscaloosa, Ala., on the Black Warrior River, was 56.2 feet, 10.2 feet above flood stage, on March 12. A peculiarity of this flood was the unprecedentedly small rise of the Tombigbee River at Columbus, Miss., and Cochrane, Ala., a rainfall of 5.8 inches raising the river at Columbus only 4.7 feet in 4 days.

The warnings were of great value to lumbermen by affording them ample opportunity to make preparations for floating out lumber from the lowlands as well as to others who were enabled to remove portable property.

Ohio Basin.—The Ohio River flood began after the heavy rains of March 14 and 15. The flood was a very moderate one above Cincinnati, and flood stages were not reached, except in a very few localities. At Cincinnati the crest stage of 52.2 feet, at 4 p. m., March 18, was too low to cause any damage. From the mouth of the Kentucky River to Louisville, Ky., the crest stages were also only slightly in excess of the flood stages, but from Cloverport, Ky., to the mouth of the river they were from 6.5 to 8.5 feet above.

Crest stages were as follows:

Station.	Flood stage.	Crest stage.	Date.
Cincinnati, Ohio	52	52.2	Mar. 18.
Madison, Ind	46	46.1	Mar. 19.
Louisville, Ky	28	30.2	Mar. 19.
Cloverport, Ky	40	46.4	Mar. 20.
Evansville, Ind	35	42.9	Mar. 21.
Henderson, Ky	33	41.3	Mar. 21 and 22.
Mount Vernon, Ind	35	43.5	Mar. 23.
Shawneetown, Ill	35	....	
Paducah, Ky	43	48.8	Mar. 24 and 25.
Cairo, Ill	45	53.6	Mar. 26 and 27.

There were also two floods in the Barren and upper Green Rivers of Kentucky, and a continuous flood in the lower Green River, all of which were forecast at the proper time.

There were no material losses during these floods. Shippingport, a suburb of Louisville, was flooded as to its streets and yards, but the residents upon the advice of the Weather Bureau remained in their homes.

The floods in the Wabash and White Rivers of Indiana continued at the close of the month, and report thereon will be made later with that on the Ohio River flood from the mouth of the Wabash to Cairo, Ill.

The floods in the Cumberland and Tennessee Rivers will be described in the later report on the lower Mississippi flood.

Lake Erie drainage.—There was a moderate local flood on March 15 in the Maumee River at Fort Wayne, Ind. It was due to the rains of March 14, and the crest stage was only 0.4 foot above the flood stage of 15 feet. The

heavy rains at the end of the month caused a general and more pronounced flood in the Maumee River and its tributaries during March 31 and the early days of April. The crest stage at Fort Wayne was 19.4 feet at 7 a. m., April 1, but at other points on the rivers the crest stages were not as high proportionately except in the St. Joseph River.

Very accurate warnings were issued for the floods and there was no damage of consequence. Access to some homes in Fort Wayne was cut off by the high water, and there was a little damage from seepage.

The heavy rains near the middle of the month of March were very widely distributed, and the flood area extended west of the Mississippi River into the central West. They occurred mainly in eastern Kansas, and were of moderate character, except over limited areas. A local cloud-burst over the drainage area of Rock Creek, a small tributary of the Neosho River, at Burlington, Kans., flooded the city during the night of March 23, killing four persons and doing damage to an estimated amount of $750,000. It was reported that at the height of the flood a wall of water 12 feet high rushed through the business section of the city.

The floods in the larger rivers were forecast, and the damage was small.

A severe flood, caused by an ice gorge in the Rock River, occurred at Dixon, Ill., beginning on March 2, and continued for several days. Many families were driven from their homes, the city gas plant was flooded, causing a fuel famine, and much business was interrupted.

There were no floods in the far West.

MOVEMENT OF ICE.

The ice in the Mississippi River moved out at St. Paul, Minn., during the night of March 4 and 5, at La Crosse, Wis., on March 16; and at Dubuque, Iowa, on March 6. Below Dubuque the river was open. In the Missouri River the ice at Sioux City, Iowa, moved out on March 13; at Yankton, S. Dak., on March 15; and at Chamberlain, S. Dak., on March 16; and at Pierce, S. S. Dak., on March 17. There was no attendant high water.

Flood stages during March, 1922.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Connecticut:	*Feet.*			*Feet.*	
White River Junction, Vt	13	8	12	16.0	9
Do	13	15	15	18.2	15
Do	13	28	(**)	19.5	30
Hartford, Conn	16	30	(**)	19.9	31
Susquehanna:					
Bainbridge, N. Y	11	8	8	12.7	8
Chenango:					
Greene, N. Y	8	8	8	8.4	8
James:					
Columbia, Va	18	12	12	19.0	12
Do	18	16	17	19.8	16
Roanoke:					
Randolph, Va	21	5	5	21.6	5
Weldon, N. C	30	4	8	39.6	6
Do	30	11	14	35.4	13
Tar:					
Rocky Mount, N. C	9	5	9	10.4	6
Tarboro, N. C	18	5	16	25.2	9
Greenville, N. C	14	4	18	19.1	11
Fishing Creek:					
Enfield, N. C	14	5	7	15.6	6
Neuse:					
Neuse, N. C	14	3	14	18.6	5
Smithfield, N. C	14	4	15	19.6	6
Cape Fear:					
Elizabethtown, N. C	22	4	16	31.7	7
Fayetteville, N. C	35	5	13	44.3	6

** Continued into April.

Flood stages during March, 1922—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE—continued.					
Peedee:	*Feet.*			*Feet.*	
Cheraw, S. C	27	4	6	33.5	5
Do	27	8	9	31.3	8
Do	27	12	13	30.2	12
Lynches:					
Effingham, S. C	14	10	15	17.3	12
Black:					
Kingstree, S. C	12	12	17	12.6	14-15
Santee:					
Rimini, S. C	12	(*)	(**)	18.0	11
Ferguson, S. C	12	(*)	(**)	14.2	13
Wateree:					
Camden, S. C	24	7	9	27.2	8
Do	24	12	12	24.2	12
Congaree:					
Columbia, S. C	15	7	8	18.8	7
Broad:					
Blairs, S. C	15	11	12	15.5	11-12
Carlton, Ga	11	11	11	15.8	11
Saluda:					
Pelzer, S. C	7	11	12	9.0	11
Chappells, S. C	14	8	8	16.0	8
Do	14	11	14	17.0	12
Do	14	21	21	15.5	21
Savannah:					
Augusta, Ga	32	12	12	32.0	12
Oconee:					
Milledgeville, Ga	22	7	9	32.0	7
Do	22	11	13	29.2	12
Do	22	21	21	22.0	21
Dublin, Ga	22	10	11	24.3	10
Do	22	14	15	23.6	14
Ocmulgee:					
Macon, Ga	18	7	8	20.8	7
Do	18	11	13	23.2	11
Hawkinsville, Ga	29	14	14	29.0	14
Abbeville, Ga	11	9	22	16.4	12, 16
Do	11	25	29	12.3	27
Lumber City, Ga	15	14	23	18.5	16
EAST GULF DRAINAGE.					
Apalachicola:					
River Junction, Fla	12	4	(**)	23.8	15
Blountstown, Fla	15	5	(**)	22.2	16
Flint:					
Woodbury, Ga	10	8	8	10.0	8
Do	10	11	12	12.2	11
Montezuma, Ga	20	9	10	21.2	10
Do	20	13	13	20.9	13
Albany, Ga	20	11	19	26.8	16
Bainbridge, Ga	25	15	20	26.6	18
Chattahoochee:					
West Point, Ga	20	11	11	20.0	11
Eufaula, Ala	40	8	10	46.6	9
Do	40	13	13	40.6	13
Alaga, Ala	30	8	15	37.6	10
Alabama:					
Montgomery, Ala	35	8	17	48.0	13
Selma, Ala	35	7	23	49.6	14
Tallapoosa:					
Milstead, Ala	40	8	8	44.0	8
Do	40	11	11	40.1	11
Coosa:					
Gadsden, Ala	22	11	17	23.2	12-13
Lock No. 4, Lincoln, Ala	17	10	18	20.5	11
Wetumpka, Ala	45	11	13	47.0	12
Etowah:					
Canton, Ga	11	11	11	11.1	11
Cahaba:					
Centerville, Ala	25	11	11	25.0	11
Tombigbee:					
Aberdeen, Miss	33	4	5	33.5	4
Do	33	14	14	33.1	14
Lock No. 4, Demopolis, Ala	39	3	27	56.5	19-20
Black Warrior:					
Lock No. 10, Tuscaloosa, Ala	46	3	5	53.0	3
Do	46	11	13	56.2	12
Chickasawhay:					
Enterprise, Miss	21	3	4	23.0	3
Pearl:					
Edinburg, Miss	21	4	6	22.4	5
Do	21	13	15	22.3	14
Jackson, Miss	20	1	25	28.8	11
Columbia, Miss	18	4	27	19.9	13, 18
West Pearl:					
Pearl River, La	13	4	(**)	15.5	29
GREAT LAKES DRAINAGE.					
Maumee:					
Fort Wayne, Ind	15	31	(**)	18.4	31
St. Joseph:					
Montpelier, Ohio	10	11	11	10.0	11
Do	10	31	(**)	11.0	31
Auglaize:					
Defiance, Ohio	10	31	31	10.0	31

* Continued from February.
** Continued into April.

Flood stages during March, 1922—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
MISSISSIPPI DRAINAGE.					
Ohio:	*Feet.*			*Feet.*	
Portsmouth, Ohio	50	17	17	51.0	17
Dam No. 35, Oneonta, Ky	45	17	19	46.6	18
Cincinnati, Ohio	50	16	20	52.2	18
Madison, Ind	46	19	19	46.1	19
Louisville, Ky	28	16	21	30.2	19
Cloverport, Ky	40	16	24	46.4	20
Evansville, Ind	35	14	28	42.9	21
Henderson, Ky	33	15	28	41.3	21-22
Dam No. 48, Ind	42	15	28	40.5	22
Mount Vernon, Ind	35	15	30	43.5	23
Shawneetown, Ill	35	15	(**)	47.6	25
Paducah, Ky	43	17	(**)	48.8	24
Cairo, Ill	45	16	(**)	53.6	25-27
Tuscarawas:					
Norris Point, Ohio	8	31	(**)	8.3	31
Hocking:					
Athens, Ohio	17	15	16	19.8	16
Scioto:					
Circleville, Ohio	10	15	16	11.7	16
Chillicothe, Ohio	16	16	16	16.5	16
Kentucky:					
Beattyville, Ky	30	11	11	31.2	11
Green:					
Lock No. 6, Brownsville, Ky	30	4	5	32.4	5
Do	30	17	17	30.5	17
Lock No. 4, Woodbury, Ky	33	3	8	40.7	5
Do	33	11	20	40.4	17
Lock No. 2, Rumsey, Ky	34	(*)	2	35.1	1
Do	34	6	30	40.8	21-22
Big Barren:					
Bowling Green, Ky	20	3	3	25.3	3
Wabash:					
Lafayette, Ind	11	12	18	17.4	16
Do	11	29	(**)	16.5	31
Terre Haute, Ind	16	15	23	19.7	16
Vincennes, Ind	14	17	29	18.9	21
Do	14	31	(**)	14.7	31
Mount Carmel, Ill	15	16	(**)	24.1	22-23
White:					
Decker, Ind	18	18	28	24.6	22
Do	18	31	(**)	18.3	31
Georgetown, Ark	22	17	22	22.4	21
Do	22	31	(**)	22.1	31
East Fork of White:					
Williams, Ind	10	18	23	15.4	19
Shoals, Ind	20	19	23	26.3	20
West Fork of White:					
Anderson, Ind	12	15	16	12.1	15
Noblesville, Ind	14	16	16	14.0	16
Elliston, Ind	19	15	22	26.3	17
Do	19	31	(**)	21.6	31
Cumberland:					
Carthage, Tenn	40	3	6	44.0	4
Do	40	12	16	43.5	12
Nashville, Tenn	40	3	20	45.1	12
Clarksville, Tenn	46	4	21	51.3	16
French Broad:					
Penrose, N. C	13	28	28	14.1	28
North Fork of Holston:					
Mendota, Va	8	11	11	8.2	11
Do	8	16	16	8.7	16
Hiwassee:					
Charleston, Tenn	22	11	11	22.6	11
Tennessee:					
Knoxville, Tenn	12	11	12	13.0	12
Guntersville, Ala	31	15	15	31.0	15
Florence, Ala	18	3	8	20.0	5
Do	18	10	18	21.5	11
Savannah, Tenn	40	10	21	43.5	16
Riverton, Ala	32	3	22	42.8	11
Johnsonville, Tenn	31	7	7	31.0	7
Do	31	10	24	36.4	15
Duck:					
Columbia, Tenn	30	2	3	32.0	3
Do	30	10	11	31.4	11
Mississippi:					
Louisiana, Mo	12	16	16	12.3	16
Grafton, Ill	18	17	17	18.4	17
Alton, Ill	21	16	19	23.0	17
Do	21	27	(**)	22.4	28
Cape Girardeau, Mo	30	28	(**)	30.8	29
New Madrid, Mo	34	16	(**)	41.6	27-28
Memphis, Tenn	35	20	(**)	42.6	31
Helena, Ark	42	19	(**)	51.4	31
Arkansas City, Ark	42	17	(**)	53.0	31
Greenville, Miss	42	28	(**)	45.4	31
Vicksburg, Miss	45	28	(**)	47.6	31
Natchez, Miss	46	31	(**)	46.2	31
New Orleans, La	18	31	(**)	18.0	31
Illinois:					
Morris, Ill	13	21	22	13.6	21
Do	13	31	(**)	14.1	31
Peru, Ill	14	13	(**)	17.9	31
Henry, Ill	7	12	(**)	12.1	31
Peoria, Ill	16	19	(**)	19.2	31
Havana, Ill	14	20	(**)	16.9	31
Beardstown, Ill	12	14	(**)	18.8	31
Pearl, Ill	12	16	(**)	16.3	31

** Continued into April.
* Continued from February.

Flood stages during March, 1922—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
MISSISSIPPI DRAINAGE—continued.					
Missouri:	*Feet.*			*Feet.*	
St. Charles, Mo	25	27	27	25.4	27
Osage:					
Osceola, Mo	20	19	22	21.8	20
Do	20	31	(**)	20.0	31
Warsaw, Mo	22	15	22	26.7	15
Do	22	31	(**)	23.9	31
Tuscumbia, Mo	25	17	22	26.0	21
Do	25	31	(**)	26.7	31
Meramec:					
Pacific, Mo	11	16	17	12.7	16
Do	11	28	29	12.2	28
Bourbeuse:					
Union, Mo	10	15	16	11.3	16
Do	10	28	28	11.6	28
St. Francis:					
Marked Tree, Ark	17	28	(**)	18.1	31
Yazoo:					
Yazoo City, Miss	25	21	(**)	29.1	31
Tallahatchie:					
Swan Lake, Miss	25	5	(**)	29.2	19-21
Ouachita:					
Camden, Ark	30	30	(**)	32.1	31
James:					
Huron, S. Dak	9	16	(**)	16.5	22
Neosho:					
Le Roy, Kans	24	25	25	24.8	25
Iola, Kans	10	18	18	10.2	18
Do	10	25	26	18.4	26
North Canadian:					
Woodward, Okla	3	11	11	3.2	11
Do	3	13	23	6.0	15
Canton, Okla	3	15	17	4.1	16
Oklahoma City, Okla	12	22	22	12.1	22
Arkansas:					
Wichita, Kans	9	15	16	10.2	15
Little Arkansas:					
Sedgwick, Kans	18	14	15	23.4	14
Petit Jean:					
Danville, Ark	20	31	(**)	20.1	31
Black:					
Black Rock, Ark	14	10	(**)	20.7	31
Cache:					
Patterson, Ark	9	11	(**)	10.2	31
Sulphur:					
Finley, Tex	24	31	(**)	25.4	31
Ringo Crossing, Tex	20	27	28	22.5	27
WEST GULF DRAINAGE.					
Trinity:					
Liberty, Tex	25	4	6	25.4	5
Do	25	30	(**)	25.5	31
Sabine:					
Logansport, La	25	30	30	27.8	30
Bon Wier, Tex	20	5	15	20.4	6-7
Do	20	31	(**)	20.0	31
Neches:					
Rockland, Tex	20	4	6	21.4	4
Do	20	30	(**)	26.2	31
Guadalupe:					
Gonzales, Tex	22	30	30	31.2	30
Colorado:					
Lees Ferry, Ariz	12	22	22	12.5	22

** Continued into April.

CHANGES IN RIVER DISTRICTS.

The following changes in river districts became effective on February 1, 1922:

The district of Iola, Kans., and its territory, consisting of the drainage area of the Neosho River from Oswego, Kans., northward, were reassigned to the district of Fort Smith, Ark.

The district of San Antonio, Tex., was created with territory comprising the drainage areas of the Colorado (Texas), Guadalupe, Neches, and San Antonio Rivers, and the Rio Grande from El Paso to its mouth. These rivers were formerly in the Houston, Tex., district.

The jurisdiction of the Omaha, Nebr., center was extended so as to embrace the entire watershed of the Platte River and river stations were opened at Fort Morgan, Colo.; Torrington, Wyo.; North Platte (both rivers), Lexington, Central City, and Fremont, Nebr.

The territory of the St. Louis, Mo., district was extended so as to embrace those portions of the drainage

areas of the Black and St. Francis Rivers lying within the State of Missouri. These sections were formerly included in the Little Rock, Ark., and Memphis, Tenn., districts, respectively.

MEAN LAKE LEVELS DURING MARCH, 1922.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., Apr. 4, 1922.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during March, 1922:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.35	579.40	571.39	245.08
Above or below—				
Mean stage of February, 1922	−0.08	+0.17	+0.22	+0.38
Mean stage of March, 1921	−0.20	−0.50	−0.73	−0.71
Average stage for March, last 10 years	−0.41	−0.66	−0.38	−0.60
Highest recorded March stage	−0.93	−3.55	−2.46	−2.73
Lowest recorded March stage	+0.69	+0.29	+0.56	+0.78
Average relation of the March level to:				
February level		+0.10	+0.10	+0.20
April		−0.30	−0.70	−0.70

* Lake St. Clair's level: In March, 573.96 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, MARCH, 1922.

By J. WARREN SMITH, Meteorologist.

March, 1922, was generally mild east of the Rocky Mountains, except that the first week was unseasonably cold in the Southwest, when the line of freezing temperature extended southward to the west Gulf coast. The freeze did much damage to early truck and early planted potatoes, corn, and cotton in southern Texas, but otherwise frost damage was not important during the month east of the Rockies. The first half was abnormally cold and disagreeable in most sections west of the Rocky Mountains and was very unfavorable for stock, with considerable loss of range horses and some loss of cattle and sheep. The latter half was warmer and more favorable in that area and the melting snow opened additional ranges in the central and southern Rocky Mountain States.

Rains that had set in the latter part of February over the southern Great Plains, where severe drought had prevailed, continued during March, supplying ample soil moisture, except in some of the more southwestern districts. Winter grains showed improvement in that area, although in western Kansas recovery was slow and wheat continued in a generally poor condition. From the Great Plains eastward, winter grains continued to make satisfactory growth under the influence of ample moisture and mild temperature.

Frequent and heavy rains throughout the central portion of the country seriously interfered with the preparation of soil and the seeding of spring grains. Very little spring wheat had been sown at the close of the month and but little oats in many heavy producing sections in the Ohio and central and upper Mississippi Valleys.

The preparation of ground for corn planting was also much delayed in the interior Valley States, and excessive rains the latter part of the month were unfavorable for early planted corn in the lower Mississippi Valley and in eastern Texas. The weather was favorable for planting corn and cotton in the Southeast the latter part of the month and considerable of both crops were up to a good stand in southern Georgia at its close.

Under the influence of mild weather deciduous fruit buds developed rapidly and at the close of the month early fruits were in bloom northward to Virginia and the lower Ohio Valley. No material frost damage resulted to fruit during the month, although peaches were injured in southwestern Arkansas and some damage was reported in northwestern North Carolina the latter part. Strawberries continued in good condition and were ripening in the lower Mississippi Valley, but some damage resulted to this crop in portions of North Carolina from the cold weather.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, March, 1922.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	56.2	0.0	Maple Grove	85	28	2 stations	23	5	10.11	+4.65	Thomasville	13.98	Eufaula	5.94
Alaska														
Arizona	48.9	−4.5	2 stations	90	19†	Grand Canyon	−7	1	1.26	+0.23	Heber	3.91	Leupp	0.03
Arkansas	51.7	−0.9	Portland	83	28	Gravette	7	3	8.57	+3.87	Marked Tree	14.50	Fayetteville	3.24
California	48.5	−3.3	Indio	91	20	Huntington Lake	−10	1	3.87	−0.87	Crescent City	15.50	Bagdad	0.00
Colorado	33.1	−1.3	Lamar	80	16	Dillon	−32	2	1.42	+0.10	Savage Basin	6.71	2 stations	T.
Florida	67.4	+1.7	Lake Wales	94	30†	2 stations	28	5	2.29	−0.50	DeFuniak Springs	11.50	3 stations	0.00
Georgia	57.5	+0.7	2 stations	88	29†	Blue Ridge	20	5	8.27	+3.88	Clayton	14.40	Bainbridge	2.69
Hawaii	68.9	+0.4	2 stations	87	29†	2 stations	46	1†	13.24	+4.95	Papaikou	69.73	Kekaha	0.32
Idado	30.3	−4.7	3 stations	69	21	Felt	−35	1	1.82	+0.20	Musselshell	5.49	Idaho Falls	0.10
Illinois	42.9	+2.7	Mascoutah	78	24	Carlinville	7	3	6.32	+3.30	New Burnside	11.79	Mt. Carroll	2.17
Indiana	43.6	+3.2	4 stations	77	24†	Veedersburg	10	3	7.07	+3.34	Princeton	11.11	Goshen	3.22
Iowa	38.7	+5.1	Burlington	74	23	Fayette	−5	2	1.97	+0.20	Chariton	3.73	2 stations	0.76
Kansas	43.3	−0.1	Anthony	83	23	Scott City	−14	1	3.94	+2.59	Burlington	12.40	2 stations	0.35
Kentucky	49.4	+3.4	Ashland	83	30	Scott	19	3	8.11	+3.45	Blandville	12.68	Pikeville	4.70
Louisiana	59.9	−0.8	Ten Mile	91	28	Calhoun	18	4	9.70	+5.53	Alexandria	15.52	Clinton	5.69
Maryland-Delaware	44.3	+1.9	4 stations	80	26†	2 stations	11	1†	4.67	+1.03	Crisfield, Md	9.22	2 stations	3.38
Michigan	32.0	+2.9	4 stations	72	25	Humboldt	−23	22	2.69	+0.71	Morenci	6.47	2 stations	0.50
Minnesota	28.4	+2.7	St. Charles	66	13	Fort Ripley	−31	1	1.22	+0.04	Colquet	2.61	State Sanatorium	0.30
Mississippi	56.5	−0.9	Edinburg	87	30	3 stations	21	4	9.91	+4.46	Port Gibson	15.01	Meridian	6.20
Missouri	45.6	+1.4	Caruthersville	80	24	4 stations	3	1	6.46	+3.38	Caruthersville	13.29	Downing	1.45
Montana	29.1	−1.3	Billings	70	21	Busby	−33	1	0.70	−0.23	Heron	3.29	Foster	0.00
Nebraska	38.7	+3.0	Gothenburg	84	22	Lodgepole	−13	1	1.12	+0.02	Auburn	5.89	Chadron	T.
Nevada	37.8	−3.8	Logandale	90	21	2 stations	−16	1	0.83	−0.12	Mahoney Range	3.26	Jungo	T.
New England	33.5	+3.1	Boston, Mass	79	26	Van Buren, Me	−27	2	4.43	+0.70	2 stations	6.58	Van Buren, Me	1.25
New Jersey	41.1	+2.6	Long Branch	82	26	2 stations	2	1	4.52	+0.64	Newark	7.10	Indian Mills	3.42
New Mexico	41.4	−2.8	Pearl (near)	87	23	Wagon Mound (near)	−25	1	0.62	−0.19	Dulce	2.92	2 stations	0.00
New York	34.6	+3.1	2 stations	78	26	Spier Falls	−8	1	3.82	+0.72	Sherborne	6.19	Chazy	0.48
North Carolina	52.0	+2.2	2 stations	87	29†	Highlands	18	22	6.91	+2.63	Rock House	13.92	Wilmington	4.47
North Dakota	25.5	+2.9	Hettinger	60	22	2 stations	−30	1	0.72	−0.11	Langdon	2.05	Beach	0.04
Ohio	42.2	+3.2	4 stations	83	29†	Medina	4	3	5.15	+1.67	Wilmington	10.10	North Bass Island	2.62
Oklahoma	50.1	−1.7	3 stations	85	22†	Kenton	−18	1	4.25	+1.96	Wyandotte	10.18	Kenton	0.51
Oregon	39.0	−3.4	2 stations	73	20	Fremont	−30	1	4.22	+1.08	2 stations	16.53	Blitzen	0.09
Pennsylvania	40.0	+2.8	Gettysburg	81	26	Saegerstown	−5	23	4.37	+0.82	Girardville	6.65	Creekside	2.30
Porto Rico														
South Carolina	55.5	+0.5	Florence No. 1	89	30	Walhalla	24	5	7.04	+4.10	Monetta	10.10	Charleston	3.15
South Dakota	32.3	+2.1	2 stations	76	22	McIntosh	−25	1	0.69	−0.26	McIntosh	2.50	4 stations	0.00
Tennessee	51.2	+1.5	Newport	84	30	Crossville	19	5	9.27	+3.89	Tullahoma	13.04	Greeneville	4.04
Texas	57.7	−1.2	Falfurrias	100	13	Romero	−12	1	3.69	+1.71	Willis	17.00	5 stations	0.00
Utah	33.9	−4.6	Wendover	79	31	2 stations	−22	1	1.30	−0.20	Silver Lake	6.73	Lemay	0.01
Virginia	47.5	+2.3	Hopewell	86	29	2 stations	16	1†	5.45	+1.66	Lynchburg	7.50	Winchester	1.87
Washington	37.9	−3.6	Sixprong	70	18	Deer Park	−9	1	3.44	+0.45	Wind River	15.89	Hanford	0.26
West Virginia	45.0	+2.4	Cuba	85	25	Cheat Bridge	0	23	5.33	+1.50	Pickens	8.19	Upper Tract	1.40
Wisconsin	33.9	+1.8	Prairie du Sac	75	13	Winter	−27	2	1.90	+0.15	Stevens Point	3.82	Downing	0.10
Wyoming	29.2	−1.5	Torrington	73	22	Moran	−43	1	0.46	−0.66	Foxpark	1.70	Dwyer	0.00

*For description of tables and charts, see REVIEW, January, 1921, p. 41.

†Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1922.*

Districts and stations.	Elevation of instruments. Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air. Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation. Total.	Departure from normal.	Days with 0.01 inch, or more.	Wind. Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles.								0–10	In.	In.
New England.							36.0	+3.3										72	4.46	+0.7										5.9		
Eastport, Me.	76	67	85	29.94	30.02	+0.09	33.0	+4.1	54	14	40	3	1	26	30	29	24	74	2.70	−1.6	9	8,726	nw.	48	se.	8	7	12	12	6.0	5.3	0.0
Greenville, Me.	1,070	6																														
Portland, Me.	103	82	117	29.95	30.08	+.12	34.9	+2.9	70	26	42	8	1	27	35	30	24	69	3.86	+0.1	11	7,078	nw.	48	se.	7	14	4	13	5.3	5.9	0.6
Concord	288	70	79	29.75	30.07	+.07	34.6	+3.1	72	26	43	7	4	26	40				5.00	+1.6	11	4,147	nw.	27	nw.	29	16	4	11	4.7	8.3	4.5
Burlington	404	11	48	29.64	30.10	+.10	32.0	+4.7	60	26	40	6	1	24	27				2.88	+1.0	14	7,770	n.	46	s.	26	7	11	13	6.4	7.1	0.8
Northfield	876	12	60	29.11	30.09	+.09	29.2	+3.0	65	26	39	−4	3	19	42	26	22	77	4.55	+1.8	13	5,430	s.	39	s.	7	6	9	16	6.7	12.3	4.6
Boston	125	115	188	29.93	30.07	+.10	39.8	+4.8	79	26	48	14	1	32	41	34	27	63	4.35	+0.3	10	6,464	nw.	36	s.	7	9	7	15	5.9	10.1	2.2
Nantucket	12	14	90	30.05	30.06	+.08	38.6	+1.8	62	29	44	18	1	33	26	36	33	85	6.24	+2.3	12	13,063	sw.	54	se.	7	11	7	13	6.0	6.5	0.0
Block Island	26	11	46	30.03	30.06	+.08	37.7	+1.8	58	29	43	17	1	32	22	35	31	79	4.75	+0.4	12	14,814	sw.	48	e.	31	12	6	13	5.7	4.6	0.0
Providence	160	215	251	29.89	30.07	+.09	39.0	+3.3	75	26	47	14	1	31	37	34	27	66	4.67	0.0	12	9,904	nw.	53	s.	7	11	7	13	5.5	10.5	2.1
Hartford	159	122	140	29.91	30.09	+.10	38.3	+3.3	74	26	47	12	1	30	39	33	26	69	5.09	+0.8	15	5,920	nw.	44	s.	7	7	8	16	6.7	5.8	1.3
New Haven	106	74	153	29.98	30.10	+.11	38.8	+3.4	70	26	46	15	1	31	35	34	28	69	5.01	+0.6	14	7,686	ne.	42	s.	7	10	8	13	5.7	4.7	0.0
Middle Atlantic States.							43.4	+3.4										72	4.70	+1.1										6.1		
Albany	97	102	115	30.00	30.11	+.10	36.9	+4.8	73	26	45	8	1	29	34	32	27	73	4.69	+2.0	13	5,428	s.	29	s.	7	13	8	10	4.9	9.2	2.0
Binghamton	871	10	84	29.15	30.10	+.08	36.2	+4.2	70	26	45	11	4	27	37				3.95	+1.3	15	4,641	nw.	24	nw.	8	3	8	20	7.4	11.3	1.0
New York	314	414	454	29.74	30.09	+.09	41.3	+3.8	72	26	49	17	1	34	33	36	29	65	4.35	−0.2	13	13,949	nw.	70	s.	7	6	11	14	6.3	3.3	0.0
Harrisburg	374	94	104	29.71	30.12	+.09	41.8	+4.0	75	26	49	19	1	34	36	36	30	66	3.21	+0.1	17	5,995	nw.	32	sw.	21	8	6	17	6.4	2.5	0.0
Philadelphia	117	123	190	29.98	30.12	+.10	43.6	+3.6	75	26	52	20	1	36	35	39	33	68	4.34	+0.9	16	8,358	nw.	37	s.	7	8	6	17	6.4	1.3	0.0
Reading	325	81	98	29.75	30.12		41.8		76	26	50	18	1	34	37	38	34	77	4.11	+0.6	16	4,512	nw.	30	nw.	8	12	3	16	5.7	2.8	0.0
Scranton	805	111	119	29.22	30.11	+.09	38.7	+3.8	73	26	47	14	1	30	35	34	29	72	4.02	+0.9	13	5,718	nw.	33	sw.	7	6	10	15	6.7	5.7	0.0
Atlantic City	52	37	48	30.05	30.11	+.09	41.6	+2.8	70	29	48	20	1	36	27	38	35	80	4.38	+0.6	14	15,003	nw.	68	s.	7	11	6	14	5.7	T.	0.0
Cape May	18	13	49	30.12	30.14	+.13	42.2	+1.4	68	29	48	20	18	36	23	38	35	81	4.55	+0.8	14	7,720	nw.	45	se.	7	10	3	18	6.3	T.	0.0
Sandy Hook	22	10	55	30.07	30.09		40.2		69	26	46	20	1	34	31	36	31	72	3.94		15	12,997	nw.	62	s.	7	8	9	14	5.8	3.9	0.0
Trenton	190	159	183	29.89	30.10		41.2		74	26	50	17	1	33	39	38	34	78	3.89	−0.2	14	9,902	nw.	48	s.	7	9	6	16	6.4	2.0	0.0
Baltimore	123	100	113	29.99	30.12	+.09	44.8	+2.9	78	26	52	24	18	37	34	39	34	68	4.83	+1.0	16	5,013	nw.	26	ne.	4	9	5	17	6.2	0.1	0.0
Washington	112	62	85	30.00	30.12	+.08	45.4	+3.2	78	26	54	23	1	37	37	39	32	65	4.74	+0.9	14	5,941	nw.	40	nw.	7	8	8	15	6.5	4.5	0.0
Lynchburg	681	153	188	29.36	30.12	+.07	48.8	+3.4	79	29	59	24	1	38	43	43	38	72	7.50	+3.7	15	6,229	sw.	38	n.	8	11	5	15	5.5	0.4	0.0
Norfolk	91	170	205	30.03	30.13	+.10	51.2	+3.5	79	29	60	31	23	42	38	45	40	73	4.95	+0.7	13	10,826	ne.	54	nw.	7	10	8	13	5.5	T.	0.0
Richmond	144	11	52	29.97	30.13	+.09	49.4	+2.5	80	29	59	27	23	40	37	43	38	72	7.01	+3.3	13	6,649	s.	46	sw.	7	13	4	14	5.2	0.1	0.0
Wytheville	2,304	49	56	27.70	30.11	+.06	45.8	+3.5	73	29	56	24	1	36	38	40	35	73	4.74	+0.3	13	5,887	w.	33	nw.	8	9	4	18	6.4	0.2	0.0
South Atlantic States.							56.5	+2.7										75	5.46	+1.2										5.2		
Asheville	2,255	70	84	27.73	30.12	+.06	48.6	+3.7	75	29	57	29	23	40	37	42	38	73	4.69	−0.4	15	8,619	se.	35	se.	31	7	11	13	6.0	0.2	0.0
Charlotte	779	55	62	29.27	30.12	+.07	53.2	+2.4	79	29	63	29	2	44	30	46	41	71	6.32	+1.8	14	4,941	ne.	32	sw.	7	9	5	17	6.1	0.0	0.0
Hatteras	11	12	50	30.12	30.13	+.09	54.7	+3.3	73	30	61	36	24	48	24	51	48	80	6.95	+1.5	11	12,426	sw.	55	nw.	15	12	7	12	4.9	0.0	0.0
Manteo	12	5	42				50.7		82	29	60	31	23	42	32				6.26		7		s.				15	5	11		0.0	0.0
Raleigh	376	103	110	29.72	30.12	+.07	52.8	+2.4	82	29	63	30	1	42	36	47	45	78	5.47	+1.2	13	6,930	sw.	52	w.	7	11	7	13	5.5	0.0	0.0
Wilmington	78	81	91	30.07	30.16	+.11	56.8	+3.1	79	29	66	35	23	48	29	51	47	76	4.47	+0.9	10	7,323	sw.	36	w.	20	13	9	9	4.6	0.0	0.0
Charleston	48	11	92	30.09	30.14	+.08	59.0	+1.8	80	29	67	36	5	51	26	53	50	77	3.15	−0.6	13	9,008	s.	39	ne.	1	15	10	6	4.3	0.0	0.0
Columbia, S. C.	351	41	57	29.76	30.15	+.09	56.7	+2.7	81	29	67	32	5	46	33	49	44	72	6.51	+2.8	13	6,212	s.	39	sw.	7	9	11	11	5.0	0.0	0.0
Due West	711	10	55	29.36	30.14		53.2		79	30	63	29	5	43	32				7.98		14	7,218	s.	42	w.	7	8	11	12	5.7	0.0	0.0
Greenville, S. C.	1,039	113	122	28.99	30.10		53.0		80	30	62	30	1	44	31	47	41	71	5.95		15	7,274	sw.	48	w.	7	10	8	13	5.5	0.0	0.0
Augusta	180	62	77	29.92	30.12	+.06	57.6	+1.7	83	29	68	33	5	48	32	52	48	76	8.62	+3.8	14	5,028	s.	34	w.	31	11	10	10	5.4	0.0	0.0
Savannah	65	150	194	30.07	30.14	+.08	61.2	+2.9	83	29	70	36	5	53	29	55	51	78	4.68	+1.0	10	10,404	s.	41	s.	19	14	11	6	4.3	0.0	0.0
Jacksonville	43	209	245	30.08	30.13	+.07	64.8	+2.9	83	29	72	40	5	57	25	58	54	76	3.69	+0.2	7	10,963	se.	45	sw.	19	12	12	7	4.6	0.0	0.0
Florida Peninsula.							72.7	+2.3										74	0.48	−1.9										3.7		
Key West	22	10	64	30.06	30.08	+.03	76.0	+3.2	85	12	80	62	23	71	14	68	65	73	0.08	−1.4	3	10,015	se.	26	e.	25	21	8	2	2.7	0.0	0.0
Miami	25	71	79	30.10	30.13	+.08	72.8	+0.8	86	11	78	52	23	68	20	66	62	72	0.13	−2.6	5	8,330	e.	23	e.	30	12	16	3	4.6	0.0	0.0
Sand Key	23	39	72	30.07	30.10	+.05	73.6		79	12	76	63	23	72	9	68	66	76	0.27		5	13,839	se.	36	ne.	22	24	4	3	2.8	0.0	0.0
Tampa	35	79	92	30.08	30.12	+.05	69.2	+2.9	85	30	78	44	5	60	31	62	59	77	1.24	−1.6	7	6,118	ne.	28	sw.	20	12	15	4	4.6	0.0	0.0
East Gulf States.							58.0	+0.7										76	8.44	+2.6										5.6		
Atlanta	1,174	190	216	28.87	30.12	+.06	53.6	+1.2	78	30	62	31	3	45	28	49	46	80	10.30	+4.5	17	10,136	nw.	44	w.	31	11	2	18	6.1	0.0	0.0
Macon	370	78	87	29.72	30.12	+.06	57.2	+2.4	82	30	67	29	5	48	34	51	47	73	10.70	+5.2	10	5,522	s.	31	s.	10	11	3	17	5.6	0.0	0.0
Thomasville	273	49	58	29.82	30.12	+.06	62.0	+1.8	82	30	72	33	5	52	33	54	49	70	4.12	−1.0	10	4,247	e.	27	s.	19	8	11	12	5.6	0.0	0.0
Pensacola	56	149	185	30.04	30.10	+.04	60.6	−0.5	76	31	67	32	4	54	31	56	52	79	6.01	+0.6	11	12,526	se.	47	sw.	19	10	10	11	5.5	0.0	0.0
Anniston	741	9	57	29.35	30.12	+.06	54.4	+1.9	81	30	65	27	5	44	38				8.76	+3.0	14	5,873	se.	30	w.	31	8	13	10	5.5	0.0	0.0
Birmingham	700	11	48	29.34	30.12	+.06	55.4	+0.2	77	19	65	29	3	46	32	48	42	68	7.14	+1.4	15	7,557	se.	44	se.	1	8	10	13	6.0	0.0	0.0
Mobile	57	125	161	30.03	30.09	+.03	60.2	+1.1	80	31	68	33	3	52	25	54	51	78	11.46	+4.3	10	9,542	se.	47	se.	28	6	18	7	5.7	0.0	0.0
Montgomery	223	100	112	29.86	30.12	+.06	58.3	+0.4	83	30	67	32	5	49	30	52	48	75	11.38	+5.0	13	6,164	se.	30	nw.	7	11	8	12	5.4	T.	0.0
Corinth	469	6					53.3		80	30	63	28	2	44	36				10.64		13		s.				6	12	13		0.0	0.0
Meridian	375	85	93	29.68	30.08	+.03	56.4	+0.1	81	30	66	29	3	46	34	50	46	74	6.20	+0.6	11	5,539	se.	28	w.	19	9	7	15	5.7	0.0	0.0
Vicksburg	247	65	73	29.80	30.08	+.04	56.9	−1.3	82	28	65	28	3	48	32	52	49	82	8.37	+2.1	14	7,070	se.	35	w.	30	13	5	13	5.5	T.	0.0
New Orleans	53	76	84	30.02	30.08	+.04	62.5	+0.5	83	30	70	35	3	54	27	57	55	81	8.45	+3.2	12	6,653	se.	29	sw.	19	12	8	11	5.5	0.0	0.0
West Gulf States.							57.2	−0.7										71	4.43	+1.4										5.1		
Shreveport	249	77	93	29.78	30.05	+.03	57.1	−1.1	82	13	67	26	3	48	32	50	45	71	9.31	+4.8	11	7,207	se.	34	w.	30	13	9	9	4.7	0.0	0.0
Bentonville	1,303	11	44				47.4	+0.1	73	23	57	29	1	38	33				4.98		11						12	6	13		T.	0.0
Fort Smith	457	79	94	29.52	30.01	.00	51.6	+0.3	77	23	61	19	2	42	32	46	41	71	4.28	+0.7	12	8,347	e.	42	sw.	19	10	6	15	6.0	0.0	0.0
Little Rock	357	136	144	29.65	30.03	.00	52.4	−0.3	77	23	61	21	2	44	30	46	41	72	8.30	+3.4	12	8,099	s.	45	nw.	30	9	7	15	5.9	0.0	0.0
Brownsville	57	4	26				68.6		92	6	79	31	1	59	39				1.29		9										0.0	0.0
Corpus Christi	20	69	77	30.02	30.04	+.06	64.6	+0.2	89	14	72	29	1	57	33	58	54	76	0.65	−1.2	8	10,294	se.	47	s.	13	12	9	10	5.0	0.0	0.0
Dallas	512	109	117	29.47	30.02		55.8		80	30	67	18	2	45	37				1.82		10	9,744	se.	45	sw.	9	13	12	6	4.1	0.1	0.0
Fort Worth	670	106	114	29.27	29.99	+.01	56.4	−0.2	81	22	68	18	1	45	38	48	40	62	1.57	−0.2	7	10,272	nw.	42	w.	10	11	10	10	4.8	T.	0.0
Galveston	54	106	114	30.00	30.06	+.05	61.6	−0.7	80	14	67	33	3	56	18	57	54	80	2.69	−0.2	8	9,927	e.	49	se.	29	10	8	13	5.3	0.0	0.0
Groesbeck	461	11	56	29.54	30.03		56.8		82	13	68	20	2	46	37				5.41		7	11,081	se.	52	nw.	29	12	9	10	4.8	T.	0.0
Houston	138	111	121	29.89	30.04		61.1	−2.4	82	30	70	29	3	52	27				10.66		9	8,201	se.	38	s.	13	12	3	16	5.5	0.0	0.0
Palestine	510	64	72	29.50	30.04	+.04	57.0	−1.5	80	28	67	22	2	47	30	49	43	67	6.93	+3.5	8	7,829	se.	30	w.	9	11	8	12	5.3	0.0	0.0
Port Arthur	34	58	66	30.00	30.04		60.8		79	14	68	31	3	54	26	55	51	77	3.83		11	9,329	se.	42	se.	29	13	5	13	4.8	0.0	0.0
San Antonio	701	119	132	29.28	30.01	+.03	61.6	−0.5	85	14	73	22	1	50	35	52	44	62	3.29	+1.6	7	7,249	se.	32	nw.	1	15	7	9	4.5	0.0	0.0
Taylor	582	55	63	29.43	30.05	+.06	58.4	−1.3	81	28	70	20	2	47	38				2.89	+0.3	5	8,489	se.	34	s.	5	11	9	11	5.2	T.	0.0

103464—22——4

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1922*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.													Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
Ohio Valley and Tennessee.	Ft.	Ft.	Ft.	In.	In.	In.	°F. 47.3	°F. +3.3	°F.		°F.	°F.		°F.	°F.	°F.	°F.	% 73	In. 7.05	In. +2.6		Miles.								0-10 7.0	In.	In.
Chattanooga	762	189	213	29.29	30.11	+0.05	53.0	+1.7	77	28	62	29	5	44	32	46	40	68	9.80	+3.6	17	7,246	w.	46	sw.	31	7	6	18	6.6	T.	0.0
Knoxville	996	102	111	29.02	30.09	+.03	51.8	+3.6	79	30	61	30	5	43	34	46	40	71	7.60	+2.0	15	5,260	sw.	40	sw.	30	7	4	20	7.2	T.	0.0
Memphis	399	76	97	29.66	30.09	+.05	52.9	+0.8	74	25	60	25	2	46	24	47	42	71	8.24	+2.5	12	8,135	se.	48	sw.	19	9	2	20	6.5	T.	0.0
Nashville	546	168	191	29.50	30.09	+.04	51.3	+2.1	79	30	59	26	2	43	33	46	41	73	9.32	+3.9	15	9,249	s.	44	w.	19	6	6	19	7.2	T.	0.0
Lexington	989	193	230	29.00	30.08	+.03	46.8	+3.4	76	30	55	25	2	39	31	......	......	......	7.75	+3.0	17	12,593	sw.	58	sw.	30	7	3	21	7.2	2.8	0.0
Louisville	525	219	255	29.50	30.09	+.04	48.8	+3.5	76	30	57	25	2	41	32	43	38	72	6.46	+2.1	17	10,717	s.	69	sw.	30	6	10	15	6.6	0.7	0.0
Evansville	431	139	175	29.59	30.07	+.03	48.6	+4.0	73	24	56	26	2	41	29	43	38	72	8.20	+3.6	16	10,441	sw.	52	w.	19	5	10	16	6.9	0.1	0.0
Indianapolis	822	194	230	29.16	30.06	+.02	43.6	+4.0	72	25	52	21	1	36	33	39	34	74	7.16	+3.2	16	10,670	s.	42	w.	19	6	5	20	7.5	1.2	0.0
Royal Center	736	11	55	29.25	30.07	......	39.2	......	70	25	47	18	3	32	32	......	......	......	5.91	......	17	9,729	e.	38	e.	17	7	4	20	7.2	3.9	0.7
Terre Haute	575	96	129	29.40	30.03	......	44.4	......	74	24	52	22	3	37	30	40	36	77	8.45	......	17	9,143	nw.	38	nw.	19	7	6	18	6.8	2.5	0.0
Cincinnati	628	11	51	29.39	30.08	+.03	44.8	+4.0	76	30	53	21	1	36	36	......	36	75	6.56	+2.9	19	7,307	ne.	54	sw.	30	8	3	20	7.0	6.4	0.0
Columbus	824	179	222	29.18	30.07	+.03	43.2	+4.0	73	25	52	20	3	35	36	38	33	72	4.54	+1.3	15	9,897	se.	50	sw.	30	5	7	19	7.3	3.1	0.0
Dayton	899	181	216	29.07	30.04	......	43.6	+3.3	73	25	52	20	5	36	33	39	35	76	5.81	+2.4	17	9,600	sw.	44	sw.	30	8	3	20	7.0	3.1	0.0
Elkins	1,947	59	67	28.01	30.11	+.06	43.6	+4.5	75	25	54	12	23	33	49	38	33	73	5.32	+1.2	19	4,983	w.	34	w.	31	6	6	19	7.3	6.0	0.0
Parkersburg	638	77	84	29.43	30.10	+.05	46.7	+4.4	78	25	56	22	1	37	39	40	35	70	6.06	+2.2	16	4,831	se.	30	nw.	31	9	6	16	6.2	1.0	0.0
Pittsburgh	842	353	410	29.17	30.10	+.06	43.0	+3.5	75	25	51	18	1	35	34	38	33	72	5.84	+2.8	17	8,987	nw.	44	w.	7	8	2	21	7.1	11.0	0.0
Lower Lake Region.							**36.5**	**+3.6**										**75**	**4.11**	**+1.5**										**6.5**		
Buffalo	767	247	280	29.23	30.09	+.07	35.2	+4.0	65	25	43	16	1	28	30	32	28	77	3.61	+1.0	17	11,709	e.	50	sw.	7	5	9	17	7.1	9.0	0.0
Canton	448	10	61	29.59	30.08	......	32.0	+4.3	57	28	40	−4	1	24	26	......	......	......	3.21	+0.4	11	7,604	w.	39	w.	8	17	5	9	4.2	8.2	3.0
Oswego	335	76	91	......	30.10	+.09	34.2	+2.8	59	28	41	11	1	28	27	......	......	......	3.42	+0.6	15	7,895	nw.	31	nw.	8	6	6	19	......	10.5	3.0
Rochester	523	86	102	29.52	30.14	+.09	36.0	+4.7	68	25	43	18	18	29	34	32	26	70	3.11	+0.2	15	6,408	nw.	33	nw.	8	5	8	18	7.0	8.1	0.5
Syracuse	597	97	113	29.46	30.11	+.09	35.1	+3.7	66	28	43	9	1	28	34	......	......	......	4.68	+2.3	16	8,500	nw.	44	nw.	8	4	10	17	6.9	13.5	3.0
Erie	714	130	166	29.29	30.07	+.05	37.2	+4.1	75	25	45	16	23	29	38	33	28	72	4.34	+1.7	14	10,283	ne.	55	se.	30	7	8	16	6.6	13.0	0.0
Cleveland	762	190	201	29.24	30.08	+.05	38.8	+4.6	73	25	47	18	1	31	35	35	31	78	4.02	+1.2	16	9,730	ne.	47	w.	21	4	9	18	7.3	5.7	0.0
Sandusky	629	62	103	29.40	30.10	+.03	38.6	+3.4	73	25	46	21	1	32	35	......	......	......	4.43	+1.9	15	10,672	ne.	42	w.	20	5	10	16	6.8	4.0	0.0
Toledo	628	208	243	29.39	30.09	+.06	38.4	+3.6	70	25	46	20	1	30	34	34	30	77	5.18	+2.9	16	11,937	ne.	52	sw.	20	7	8	16	6.4	7.0	0.0
Fort Wayne	856	113	124	29.13	30.08	......	38.9	0.0	71	25	46	20	1	32	36	35	31	77	6.03	......	18	8,477	e.	36	sw.	19	7	5	19	7.0	4.9	T.
Detroit	730	218	245	29.27	30.09	+.06	36.8	+3.9	71	25	45	17	1	29	35	33	29	76	5.12	+2.8	15	9,154	ne.	36	sw.	20	10	7	14	5.9	11.0	0.0
Upper Lake Region.							**31.8**	**+4.1**										**78**	**2.63**	**+0.4**										**5.8**		
Alpena	609	13	92	29.42	30.11	+.08	29.2	+4.2	54	13	37	1	1	21	35	26	22	78	1.92	−0.1	12	9,197	nw.	39	e.	19	13	7	11	5.3	7.8	2.0
Escanaba	612	54	60	29.41	30.10	+.06	27.6	+4.1	51	14	35	−3	1	20	24	25	21	82	2.21	+0.3	9	7,259	s.	39	n.	20	17	3	11	4.5	10.5	0.5
Grand Haven	632	54	89	29.37	30.08	+.05	34.9	+4.1	62	25	41	15	1	28	29	31	28	80	4.26	+1.8	12	9,758	e.	40	s.	6	8	8	15	6.1	11.3	1.4
Grand Rapids	707	70	87	29.30	30.09	+.06	36.7	+3.7	72	25	44	16	1	29	37	32	27	72	3.18	+0.7	13	5,428	e.	24	nw.	20	8	7	16	6.5	8.8	2.0
Houghton	684	62	99	29.34	30.09	+.05	27.8	+4.0	55	4	36	−5	1	20	47	......	......	......	0.66	−1.4	7	7,977	e.	43	w.	25	9	7	15	6.0	3.6	T.
Lansing	878	11	62	29.10	30.07	......	35.4	+4.1	71	25	44	14	3	26	34	31	27	79	3.69	+1.4	15	5,877	nw.	24	nw.	20	8	10	13	6.2	11.3	2.2
Ludington	637	60	66	29.37	30.08	......	33.4	......	56	25	39	11	1	28	22	30	27	80	3.36	......	11	8,843	n.	39	s.	6	13	6	12	5.3	8.7	0.8
Marquette	734	77	111	29.28	30.11	+.07	29.8	+6.1	59	13	37	6	1	23	32	26	22	77	2.72	+0.6	9	8,058	w.	38	se.	6	9	8	14	5.9	20.2	T.
Port Huron	638	70	120	29.36	30.08	+.05	34.5	+4.9	66	25	42	16	1	27	31	31	27	79	2.79	+0.4	13	9,097	ne.	40	n.	28	11	11	9	5.2	7.9	0.5
Saginaw	641	69	77	29.38	30.09	......	34.5	......	70	25	42	12	1	26	35	30	26	75	2.48	−0.2	12	7,522	ne.	28	se.	6	10	9	12	5.5	3.4	1.5
Sault Ste. Marie	614	11	52	29.40	30.12	+.09	25.3	+4.0	47	13	35	−10	2	16	43	23	20	84	1.13	−0.7	8	6,569	se.	38	nw.	15	14	7	10	5.1	5.5	T.
Chicago	823	140	310	29.16	30.07	+.04	39.4	+3.1	66	25	45	23	1	33	28	35	31	74	5.58	+3.0	14	10,939	n.	49	se.	6	8	6	17	6.4	2.8	1.1
Green Bay	617	109	144	29.40	30.08	+.04	31.0	+4.2	53	13	37	2	1	25	21	27	24	78	1.74	−0.7	6	9,129	s.	38	s.	6	6	12	13	6.5	2.6	0.0
Milwaukee	681	125	139	29.32	30.07	+.04	35.8	+4.9	64	25	42	12	1	30	27	32	27	74	1.83	−0.8	12	9,918	ne.	44	sw.	6	7	8	16	6.6	1.3	0.3
Duluth	1,133	11	47	28.82	30.08	+.02	26.2	+2.1	48	13	33	−1	1	20	26	23	20	81	2.60	+1.0	8	11,394	ne.	60	nw.	6	14	2	15	5.4	16.4	3.0
North Dakota.							**26.4**	**+5.6**										**81**	**0.80**	**−0.2**										**6.5**		
Moorhead	940	50	58	29.02	30.07	−.01	27.4	+6.0	53	13	34	−16	1	20	33	25	22	82	1.30	+0.2	10	7,238	s.	34	se.	17	6	5	20	7.1	6.0	0.1
Bismarck	1,674	8	57	28.23	30.08	+.02	27.3	+5.2	55	22	36	18	1	19	35	25	22	82	0.70	−0.3	5	7,572	e.	35	nw.	25	13	3	15	5.4	6.8	T.
Devils Lake	1,482	11	44	28.41	30.04	−.01	25.6	+7.1	49	13	33	−9	1	19	31	23	19	85	0.62	−0.4	7	8,797	sw.	36	nw.	25	6	10	15	6.6	5.3	0.5
Ellendale	1,457	10	56	28.44	30.04	......	27.8	......	52	13	35	−17	1	20	33	......	......	......	0.87	......	6	11,552	se.	48	ne.	27	8	5	18	6.7	5.6	T.
Grand Forks	835	12	89	......	......	......	26.6	......	53	13	34	−14	1	19	39	24	......	......	1.06	......	6	......	nw.	48	w.	25	14	4	13	......	7.6	2.0
Williston	1,878	41	48	27.97	30.01	−.03	25.5	+3.9	51	31	34	−17	1	17	32	23	19	76	0.58	−0.1	5	6,997	se.	36	se.	16	5	11	15	6.9	8.2	T.
Upper Mississippi Valley.							**40.1**	**+4.1**										**77**	**3.60**	**+1.2**										**6.4**		
Minneapolis	918	102	208	29.03	30.04	......	32.4	......	51	13	39	−1	1	26	28	......	......	......	1.60	0.0	9	9,318	se.	37	se.	22	9	8	14	6.0	1.4	T.
St. Paul	837	236	261	29.13	30.06	+.01	32.3	+4.1	53	13	40	−2	2	25	31	......	......	......	1.41	−0.2	11	9,830	se.	44	sw.	25	9	15	7	5.4	1.2	0.0
La Crosse	714	11	48	29.26	30.05	+.01	35.0	+4.1	66	13	44	4	2	26	30	......	......	......	1.83	+0.2	9	4,679	s.	24	sw.	6	8	8	15	6.3	6.7	0.0
Madison	974	70	78	29.00	30.09	+.05	34.1	+4.0	64	13	40	7	2	28	24	31	27	80	2.01	0.0	9	8,769	n.	39	sw.	6	7	4	20	7.0	3.7	0.4
Wausau	1,247	4	......	28.72	30.11	......	29.0	......	55	13	38	−3	2	20	35	......	......	......	1.43	......	8	......	se.	......	......		15	3	13	5.3	8.1	T.
Charles City	1,015	10	49	28.95	30.06	+.01	35.5	+7.1	64	13	44	8	2	27	29	31	28	81	1.31	−0.6	6	6,474	se.	27	s.	12	9	8	14	6.0	3.4	T.
Davenport	606	71	79	29.38	30.05	+.02	39.8	+4.4	66	23	47	13	1	33	24	36	32	77	3.40	+1.2	12	7,392	e.	30	sw.	6	8	2	21	7.1	1.6	0.0
Des Moines	861	84	97	29.09	30.02	−.02	40.6	+4.9	66	13	50	10	2	32	31	35	31	72	2.25	+0.6	9	6,856	n.	32	sw.	25	7	8	16	6.3	2.7	0.0
Dubuque	698	81	96	29.31	30.08	+.04	37.4	+4.2	67	13	44	8	2	30	26	33	29	75	1.65	−0.6	9	6,153	nw.	26	s.	6	8	6	17	6.5	3.8	T.
Keokuk	614	64	78	29.36	30.05	+.02	42.8	+4.9	72	23	50	15	1	35	27	38	34	75	3.58	+1.2	13	7,127	n.	34	sw.	6	7	6	18	6.7	2.9	0.0
Cairo	356	87	93	29.66	30.05	+.01	49.2	+2.2	72	25	56	22	2	42	24	44	39	73	8.40	+4.4	15	8,507	se.	48	sw.	19	5	3	23	7.4	T.	0.0
Peoria	609	11	45	29.37	30.05	+.02	41.2	+4.2	73	23	49	17	1	34	29	37	34	82	5.09	+2.1	13	6,757	s.	29	sw.	6	9	7	15	6.4	1.3	0.0
Springfield, Ill.	644	10	91	29.43	30.03	.00	43.7	+4.1	73	23	51	20	1	35	32	39	35	80	6.81	+3.7	15	7,953	s.	33	ne.	14	10	3	18	6.6	6.3	0.9
Hannibal	534	74	100	29.34	30.02	.00	43.7	+2.1	75	23	52	15	3	36	29	......	......	......	6.25	+3.5	12	8,154	nw.	44	e.	14	8	5	18	6.8	7.1	0.8
St. Louis	567	265	303	29.41	30.03	.00	46.2	+2.4	76	24	54	21	1	38	29	41	36	74	4.84	+1.4	13	11,661	s.	50	s.	5	8	6	17	6.7	5.2	0.0
Missouri Valley.							**40.2**	**+4.1**										**76**	**3.39**	**+1.5**										**5.8**		
Columbia, Mo.	781	11	84	29.16	30.01	−.02	44.7	+3.3	74	23	54	11	3	36	38	......	......	......	8.46	+5.4	14	7,939	se.	37	ne.	14	5	6	20	7.0	2.4	0.0
Kansas City	963	161	181	28.96	30.02	.00	45.0	+4.2	76	23	53	12	1	36	36	39	35	73	5.73	+2.9	14	9,957	se.	44	ne.	14	12	6	13	5.5	1.1	0.0
St. Joseph	967	11	49	......	......	......	43.6	......	72	23	53	8	1	34	36	......	34	74	4.08	......	11	8,226	nw.	38	nw.	28	11	6	14	5.7	1.4	0.0
Springfield, Mo.	1,324	98	104	28.60	30.02	.00	45.2	+1.7	73	23	54	13	1	36	36	40	34	76	6.45	+2.4	13	10,501	se.	40	s.	5	9	10	12	5.6	2.6	0.0
Iola	984	11	50	28.93	30.00	−.01	45.6	+3.2	78	23	55	13	1	36	37	......	......	......	7.71	+5.4	11	7,624	s.	32	ne.	14	11	4	16	6.1	T.	0.0
Topeka	987	92	107	......	......	......	44.2	+3.3	79	23	54	10	2	35	41	......	......	......	4.27	+2.0	11	9,990	s.	40	n.	19	10	7	14	5.8	2.1	0.0
Drexel	1,299	10	53	28.59	30.00	......	38.6	......	69	22	49	2	1	28	39	34	31	83	1.76	......	6	9,654	sw.	37	sw.	22	6	12	13	6.3	4.6	0.0
Lincoln	1,189	11	84	28.71	30.00	−.02	40.9	+4.9	76	22	52	3	1	30	41	36	31	74	1.77	+0.4	5	9,086	n.	38	nw.	25	10	9	12	5.9	3.3	0.0
Omaha	1,105	115	122	28.82	30.02	−.02	40.6	+4.6	71	22	50	7	1	31	39	36	31	72	1.47	+0.1	6	7,694	nw.	36	nw.	19	10	10	11	5.7	3.8	0.0
Valentine	2,598	47	54	27.23	30.00	−.03	36.0	+4.1	72	22	48	−3	1	24	40	30	25	70	0.75	−0.4	4	7,605	nw.	44	n.	6	10	14	7	4.8	6.0	0.0
Sioux City	1,135	94	164	28.79	30.04	−.01	38.0	+5.4	65	15	47	4	1	29	34	33	28	72	1.69	+0.4	7	10,481	nw.	46	nw.	25	8	8	15	6.1	6.9	0.0
Huron	1,306	59	74	28.62	30.06	.00	31.0	+4.3	64	22	40	−5	1	22	33	28	26	85	0.86	−0.1	5	7,744	se.	38	w.	25	14	7	10	4.8	4.8	0.0
Pierre	1,572	70	75	28.32	30.03	−.02	33.8	+4.3	64	13	44	−5	1	24	35	30	26	80	0.56	−0.8	4	7,979	nw.	42	nw.	24	12	10	9	5.1	3.8	0.0
Yankton	1,233	49	57	28.68	30.03	−.02	36.8	+5.6	71	22	47	2	1	27	40	......	......	......	0.93	−0.2	5	6,769	nw.	32	nw.	6	5	13	13	6.5	4.0	T.

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1922*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles.								0-10	In.	In.
Northern Slope.							**31.2**	**+0.3**										**66**	**0.52**	**−0.6**										**5.2**		
Billings	3,140	5	...	...	...	...	34.5	...	70	21	47	−12	1	22	46	...	...	...	0.07	...	2	...	nw.	...	...	...	7	18	6	...	1.2	...
Havre	2,505	11	44	27.28	29.99	−0.01	26.8	−0.5	63	21	36	−22	1	17	47	25	21	80	0.43	0.0	5	6,195	e.	32	sw.	12	8	16	7	5.1	4.3	T.
Helena	4,110	87	112	25.69	29.98	−.03	31.0	0.0	62	21	40	−9	1	22	31	26	19	64	0.79	0.0	6	5,395	sw.	30	sw.	8	2	11	18	7.6	6.1	0.0
Kalispell	2,973	48	56	...	29.96	−.03	29.9	−3.1	52	21	39	−5	1	21	29	...	...	...	0.77	−0.3	7	3,749	nw.	24	sw.	21	6	14	11	...	6.3	0.0
Miles City	2,371	26	48	27.43	30.06	+.04	28.6	0.0	60	22	39	−30	1	18	40	25	23	86	0.52	−0.2	3	3,858	se.	26	nw.	20	14	12	5	4.4	4.2	0.0
Rapid City	3,259	50	58	26.53	30.03	+.02	35.4	+3.8	70	24	47	−3	1	23	46	29	21	59	0.10	−1.0	2	6,815	w.	42	NW.	6	10	14	7	4.9	1.1	0.0
Cheyenne	6,088	84	101	23.88	29.95	−.01	33.8	+0.8	60	22	45	−15	1	22	38	27	17	51	0.33	−0.6	5	10,501	w.	53	w.	27	12	9	10	5.0	2.1	0.0
Lander	5,372	60	68	24.54	30.01	+.02	29.6	−1.4	60	23	42	−10	1	17	33	25	17	62	0.60	−1.0	5	2,910	sw.	34	w.	24	12	16	3	4.4	6.0	0.0
Sheridan	3,790	10	47	26.02	30.00	...	32.2	...	63	22	44	−13	1	20	47	27	20	66	0.34	...	6	3,794	nw.	30	nw.	24	11	14	6	4.6	2.6	0.0
Yellowstone Park	6,200	11	48	23.76	30.02	.00	26.5	0.0	47	21	36	−18	1	17	40	22	15	64	0.66	−1.5	13	7,476	s.	37	s.	24	6	15	10	5.9	4.6	9.5
North Platte	2,821	11	51	27.04	30.02	+.02	38.8	+3.5	77	22	54	2	2	24	48	30	23	64	0.47	−0.4	3	6,429	n.	40	n.	18	13	4	14	5.3	2.0	0.0
Middle Slope.							**43.1**	**+0.6**										**63**	**2.48**	**+1.0**										**5.2**		
Denver	5,292	106	113	24.61	29.93	−.02	40.3	+1.6	68	22	53	−7	1	28	36	31	18	44	0.48	−0.5	4	6,431	s.	41	n.	18	12	12	7	4.9	4.9	0.0
Pueblo	4,685	80	86	25.18	29.90	−.02	41.6	+1.0	72	22	57	−13	1	26	44	32	19	47	0.29	−0.6	2	3,778	nw.	27	w.	5	7	17	7	5.6	0.2	0.0
Concordia	1,392	50	58	28.50	30.01	.00	41.8	+1.1	76	22	52	5	2	32	37	37	32	72	2.59	+1.1	12	7,899	s.	34	nw.	19	10	9	12	5.6	5.3	0.0
Dodge City	2,509	11	51	27.36	30.01	−.04	41.0	−0.7	76	22	53	−10	2	29	38	35	30	75	3.76	+2.9	9	9,211	s.	40	n.	25	21	5	5	3.5	18.4	0.0
Wichita	1,358	139	158	28.51	29.96	−.03	44.8	+0.7	77	22	54	1	2	36	35	40	34	71	3.39	+1.1	10	11,957	s.	48	s.	8	9	10	12	5.7	1.0	0.0
Altus	1,410	5	...	...	...	...	51.3	...	84	23	65	6	2	38	47	...	...	...	2.61	...	5	...	se.	...	...	...	20	0	11	...	T.	0.0
Broken Arrow	765	11	52	29.16	29.97	...	48.5	...	76	23	58	12	2	39	32	...	...	...	4.31	...	10	12,470	s.	44	nw.	19	8	11	12	5.9	0.5	0.0
Muskogee	652	4	...	...	...	...	50.4	...	79	23	60	16	28	40	37	...	...	...	5.17	...	14	...	se.	...	...	...	14	5	12	...	0.1	0.0
Oklahoma City	1,214	10	47	28.69	29.99	+.01	49.0	−0.2	79	22	60	6	2	38	38	42	36	68	4.37	+2.0	9	12,598	s.	50	s.	8	10	12	9	5.5	T.	0.0
Southern Slope.							**53.2**	**−0.1**										**49**	**1.62**	**+0.7**										**4.2**		
Abilene	1,738	10	52	28.16	29.98	+.02	55.8	+0.9	84	5	69	10	2	43	47	44	31	49	1.21	−0.2	6	11,141	s.	48	w.	9	11	13	7	4.6	0.2	0.0
Amarillo	3,676	10	49	26.20	29.97	+.02	45.3	+0.3	82	23	58	0	1	32	40	37	30	61	4.06	+3.4	7	10,263	s.	44	nw.	18	16	11	4	4.3	7.4	0.0
Del Rio	944	64	71	29.03	30.02	+.07	62.2	+0.5	88	30	74	19	1	50	38	...	...	...	0.48	−0.7	4	10,043	se.	62	nw.	9	17	6	8	3.7	0.0	0.0
Roswell	3,566	75	85	26.30	29.92	+.02	49.3	−2.0	82	23	66	2	1	33	50	36	16	37	0.72	+0.3	3	7,789	s.	52	nw.	18	14	12	5	4.2	4.4	0.0
Southern Plateau.							**47.8**	**−3.1**										**45**	**0.38**	**−0.1**										**3.3**		
El Paso	3,762	110	133	26.15	29.92	+.04	53.6	−2.3	80	16	68	14	1	39	41	39	19	31	0.16	−0.2	1	9,654	w.	64	sw.	17	19	12	0	2.5	T.	0.0
Santa Fe	7,013	57	66	23.16	29.95	+.06	36.4	−3.0	63	23	47	−2	1	26	29	28	18	54	0.44	−0.3	4	6,894	n.	39	s.	17	12	11	8	4.8	4.7	0.0
Flagstaff	6,908	10	59	23.27	29.93	+.02	32.8	−3.1	57	25	46	3	13	20	49	27	...	...	3.25	...	7	...	w.	36	sw.	28	16	11	4	...	34.2	T.
Phoenix	1,108	76	81	28.81	29.98	+.07	57.0	−3.5	83	22	70	31	1	44	38	46	36	52	0.99	+0.5	4	4,060	e.	27	nw.	8	15	10	6	3.8	0.0	0.0
Yuma	141	9	54	29.84	29.99	+.05	60.5	−4.0	87	21	74	35	3	47	38	47	31	37	0.22	−0.1	2	4,912	n.	32	nw.	11	24	3	4	2.8	0.0	0.0
Independence	3,957	9	41	25.94	30.00	+.06	46.8	−2.8	71	23	60	21	2	33	38	38	29	52	0.10	−0.4	1	6,283	nw.	36	sw.	10	22	9	0	2.5	0.8	0.0
Middle Plateau.							**37.3**	**−3.7**										**58**	**0.87**	**−0.4**										**5.5**		
Reno	4,532	74	81	25.44	30.04	+.06	38.3	−2.7	67	19	50	7	12	27	39	31	22	55	0.75	−0.5	6	6,142	w.	49	w.	7	8	14	9	5.3	4.4	0.0
Tonopah	6,090	12	20	24.01	30.02	...	35.6	...	60	22	45	9	1	26	24	29	21	59	0.14	−1.2	1	8,594	se.	41	nw.	7	5	25	1	4.5	T.	0.0
Winnemucca	4,344	18	56	25.60	30.05	+.04	33.9	−5.7	63	21	46	−2	1	22	36	29	23	66	0.79	−0.2	11	6,166	ne.	35	sw.	4	6	5	20	7.0	4.9	T.
Modena	5,479	10	43	24.55	29.96	.00	36.4	−2.8	63	20	49	7	1	24	44	28	17	49	0.45	−0.8	4	8,308	w.	55	s.	26	15	9	7	4.4	6.3	0.0
Salt Lake City	4,360	163	203	25.61	30.05	+.07	36.8	−4.6	68	23	45	12	2	28	27	31	24	63	2.44	+0.4	14	4,815	nw.	39	nw.	4	5	11	15	6.3	15.4	0.0
Grand Junction	4,602	60	68	25.33	29.94	.00	41.0	−2.5	71	23	52	12	1	30	34	33	24	55	0.65	−0.1	8	5,206	se.	34	sw.	26	11	8	12	5.5	3.4	0.0
Northern Plateau.							**37.3**	**−2.9**										**67**	**1.20**	**−0.4**										**6.8**		
Baker	3,471	48	53	26.40	30.04	+.01	31.6	−3.9	55	21	40	2	11	23	27	29	24	74	1.01	−0.4	16	5,213	se.	23	se.	12	8	11	12	6.0	6.0	0.0
Boise	2,739	78	86	27.16	30.06	+.03	38.8	−3.4	63	21	47	17	1	31	27	34	26	62	2.36	+0.9	14	5,336	se.	27	e.	31	5	9	17	7.0	3.7	0.0
Lewiston	757	40	48	29.21	30.03	.00	42.0	−2.0	60	21	51	19	1	33	25	...	...	...	0.80	−0.5	13	3,737	e.	34	s.	12	2	11	18	7.5	0.3	0.0
Pocatello	4,477	60	68	25.44	30.06	+.05	31.4	−5.5	58	23	39	−2	1	24	32	27	21	66	0.69	−1.1	8	7,800	se.	44	sw.	4	7	8	16	6.7	5.5	0.0
Spokane	1,929	101	110	27.91	30.00	−.01	36.9	−2.0	56	15	45	6	1	29	33	33	29	73	1.40	−0.1	16	5,325	sw.	36	s.	12	3	15	13	6.7	5.5	0.0
Walla Walla	991	57	65	28.92	30.01	−.01	43.2	−0.8	61	30	51	25	1	35	25	38	30	62	0.96	−0.9	12	4,697	s.	26	sw.	4	6	12	13	6.8	2.1	0.0
North Pacific coast region.							**42.4**	**−2.5**										**80**	**5.19**	**+0.6**										**7.8**		
North Head	211	11	56	29.77	30.00	−.01	41.7	−3.2	55	1	45	33	10	38	10	40	37	85	7.45	+2.2	23	13,409	s.	76	s.	3	7	8	16	7.0	1.6	0.0
Port Angeles	29	8	53	29.94	29.97	...	39.8	...	55	31	46	28	17	33	19	...	...	...	2.26	+0.1	15	4,305	s.	32	w.	12	8	9	14	6.4	6.5	0.0
Seattle	125	215	250	29.88	30.01	+.02	41.5	−2.7	56	1	47	31	11	36	21	38	34	77	4.45	+1.6	24	7,771	se.	48	s.	12	0	8	23	8.3	T.	0.0
Tacoma	213	113	120	29.78	30.01	+.01	41.3	−2.9	56	1	48	29	11	35	25	...	...	...	3.40	−0.6	24	5,047	sw.	26	sw.	3	1	8	22	8.2	T.	0.0
Tatoosh Island	86	7	57	29.85	29.95	−.01	41.2	−1.7	54	31	45	33	14	37	12	39	37	87	8.11	−0.5	26	11,642	w.	68	s.	12	3	9	19	7.6	T.	0.0
Yakima	1,071	4	...	...	...	...	40.6	...	68	12	54	13	1	28	36	...	...	...	0.74	...	3	...	nw.	...	...	...	8	14	9	...	T.	0.0
Medford	1,425	4	...	...	...	...	43.6	...	70	20	54	26	9	33	35	...	...	...	1.84	...	12	...	nw.	...	...	...	0	6	25	...	1.0	0.0
Portland, Oreg.	153	68	106	29.87	30.03	+.01	43.3	−3.0	63	31	50	30	25	37	21	40	36	76	6.57	+1.4	24	4,982	sw.	29	sw.	3	1	3	27	9.1	T.	0.0
Roseburg	510	9	57	29.51	30.07	+.03	45.2	−1.4	67	20	54	27	1	36	37	41	36	74	4.09	+0.1	18	3,039	s.	27	sw.	29	2	16	13	6.8	0.2	0.0
Middle Pacific coast region.							**49.8**	**−2.2**										**71**	**2.58**	**−1.4**										**5.8**		
Eureka	62	73	89	30.06	30.13	+.07	47.1	−0.9	61	2	53	33	11	41	20	43	40	79	6.43	−0.5	20	5,774	se.	32	sw.	15	4	9	18	7.5	0.1	0.0
Point Reyes	490	7	18	29.55	30.07	...	48.2	−1.4	56	1	52	34	11	45	15	...	...	...	1.97	...	13	14,029	nw.	61	nw.	7	8	6	17	6.3	0.0	0.0
Red Bluff	332	50	56	29.71	30.07	+.03	49.6	−4.2	72	20	59	30	11	40	31	44	37	65	1.07	−2.7	12	4,952	se.	28	se.	10	12	10	9	4.8	0.0	0.0
Sacramento	69	106	117	30.03	30.10	+.07	50.8	−3.4	67	20	59	34	11	43	23	45	39	66	1.29	−1.7	14	6,439	s.	32	se.	10	13	11	7	4.4	0.0	0.0
San Francisco	155	208	243	29.94	30.11	+.05	52.4	−0.3	69	20	58	35	11	47	21	47	42	73	2.38	−0.8	13	6,906	w.	31	nw.	17	11	9	11	5.5	T.	0.0
San Jose	141	12	110	29.96	30.12	...	50.6	−3.1	72	20	61	34	9	40	33	...	...	...	1.74	−1.2	14	4,630	nw.	24	nw.	7	8	6	17	6.5	0.0	0.0
South Pacific coast region.							**53.8**	**−1.7**										**71**	**1.99**	**−0.6**										**4.8**		
Fresno	327	89	98	29.74	30.11	+.10	52.6	−2.3	75	22	62	33	12	43	28	46	40	67	1.53	−0.2	8	4,619	nw.	29	nw.	4	10	13	8	5.5	T.	0.0
Los Angeles	338	159	191	29.71	30.07	+.05	55.6	−1.3	81	20	64	39	12	48	27	49	43	69	1.64	−1.4	5	4,605	sw.	29	s.	16	15	7	9	4.3	0.0	0.0
San Diego	87	62	70	29.98	30.07	+.05	54.6	−1.6	73	30	62	38	12	48	24	50	46	76	1.34	−0.4	8	4,888	nw.	38	s.	11	14	9	8	4.2	0.0	0.0
San Luis Obispo	201	32	40	29.90	30.13	+.07	52.2	−1.6	80	19	62	30	12	42	34	46	41	72	3.46	−0.5	9	3,271	nw.	19	nw.	27	12	13	6	5.0	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.97	30.06	...	74.1	...	81	6	78	66	13	70	13	...	...	...	3.87	+0.7	18	13,572	e.	46	e.	26	13	9	9	5.3	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Colon	25	5	71	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Alaska.																																
Juneau	80	11	49	29.71	29.80	...	31.4	...	48	29	37	14	16	26	22	27	19	64	5.08	...	13	4,704	ne.	30	ne.	17	11	5	15	6.0	9.6	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, March, 1922.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure. Station reduced to mean of 24 hours.	Pressure. Sea level reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature of the air. Mean max.+mean min.÷2.	Temperature of the air. Departure from normal.	Temperature of the air. Mean maximum.	Temperature of the air. Mean minimum.	Temperature of the air. Highest.	Temperature of the air. Lowest.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Total snowfall.
	Feet.	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*In.*	*In.*	*In.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.95	30.00	+0.12	25.9	−0.3	34.2	17.7	45	−5	1.86	−3.07	7.0
Halifax, N. S.	88	29.90	30.01	+.07	31.0	+2.0	38.6	23.3	55	−1	4.59	−0.87	16.3
Yarmouth, N. S.	65	29.93	30.00	+.05	33.9	+3.1	39.5	28.3	48	19	1.86	−2.99	3.4
Charlottetown, P. E. I.	38	29.94	29.98	+.08	27.0	+1.6	34.2	19.9	49	−2	1.59	−1.62	3.7
Chatham, N. B.	28	29.97	30.00	+.10	29.2	+6.2	38.9	19.6	52	−12	3.06	−0.41	7.0
Father Point, Que.	20	29.98	30.01	+.11	24.3	+4.3	32.2	16.4	48	−4	2.30	−0.43	8.6
Quebec, Que.	296	29.72	30.06	+.10	26.8	+5.6	35.0	18.5	50	−6	1.71	−1.55	7.6
Montreal, Que.	187	29.84	30.06	+.06	30.1	+6.3	36.6	23.7	50	4	1.84	−1.95	6.9
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.82	30.10	+.09	29.2	+7.7	38.0	20.5	56	−4	1.66	−1.06	5.7
Kingston, Ont.	285	29.77	30.10	+.09	31.7	+6.1	38.7	24.7	55	5	2.21	−0.43	5.7
Toronto, Ont.	379	29.67	30.10	+.08	34.2	+6.9	41.7	26.7	58	13	3.06	+0.42	11.6
Cochrane, Ont.	930												
White River, Ont.	1,244	28.70	30.06	+.03	20.1	+7.9	34.7	5.5	45	−27	0.59	−0.79	2.7
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.35			30.8	+6.1	38.7	23.0	60	11	2.37	−0.28	8.8
Parry Sound, Ont.	688	29.38	30.10	+.08	26.5	+5.4	36.0	17.0	46	0	2.04	−0.19	12.2
Port Arthur, Ont.	644	29.35	30.08	+.03	25.5	+8.7	34.3	16.8	51	1	1.36	+0.39	13.3
Winnipeg, Man.	760	29.19	30.06	−.03	24.7	+12.4	33.4	16.0	49	−10	1.34	+0.31	13.4
Minnedosa, Man.	1,690	28.17	30.06	.00	22.2	+9.7	30.7	13.8	44	−15	1.83	+1.18	18.3
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.66	29.98	−.06	21.5	+6.6	30.6	12.5	46	−16	1.78	+1.01	17.4
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392				23.7	+1.7	32.5	15.0	45	−10	0.16	−0.65	1.6
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.37	30.01	−.07	18.0	+6.0	29.4	6.5	46	−30	1.57	+0.80	15.7
Battleford, Sask.	1,592	28.16	29.97	−.09	19.5	+6.4	32.1	7.0	50	−15	0.65	+0.19	6.5
Kamloops, B. C.	1,262												

LATE REPORTS—FEBRUARY, 1922.

Medicine Hat, Alb.	2,144	27.74	30.14	+0.09	2.2	−9.0	14.1	−9.6	42	−30	0.58	−0.09	5.8
Banff, Alb.	4,521	25.28	30.14	+.16	4.2	−15.0	18.6	−10.3	38	−31	0.76	−0.16	7.6
Yarmouth, N. S.	65	29.96	30.03	+.04	26.4	+0.6	33.1	19.6	43	3	2.92	−1.82	21.6
St. Johns, N. F.	125	29.65	29.79	−.04	15.7	−6.3	22.4	9.0	40	−6	4.53	−0.38	33.0

SEISMOLOGICAL REPORTS FOR MARCH, 1922.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, May 3, 1922.]

TABLE 1.—*Noninstrumental earthquake reports, March, 1922.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ARKANSAS.								
1922.	*H. m.*		° ′	° ′			*Sec.*			
Mar. 22	22 20	Wilson	35 37	90 00	2	1	10 *ca.*	Rattling	Second shock at 8 p. m.	R. K. Sewell.
	22 30	Walnut Ridge	36 05	91 00	4	1	60	None	Felt by many	J. W. Pinnell.
		Weiner	35 37	90 50	3	1	15	Rumbling	Felt by one	C. E. Lasswell.
		Jonesboro	35 55	90 35	2				Felt by few, slight	Benedictine Sisters.
	22 *ca.*	Pocahontas	36 15	91 00	4?	1	Few.	Rumbling	Second shock 8.20 p. m.	Do.
	22 20	Knobel	36 15	90 35			15		Second shock 8.30 p. m.	W. A. Jesman.
	22 15	Corning	36 35	90 30		1	10-12	None	Second shock 8.15 p. m.	N. E. Skinner.
	22 20	Peach Orchard	36 15	90 40		1			Second shock 8.40 p. m.	W. S. Brown.
	22 23	Marmaduke	36 10	90 20	Faint.	1	45	Faint	Second shock 8.25 p. m.	M. A. Corbett.
23	2 20	Blytheville	35 53	89 55	4	3	10-30	None	Felt by many	J. H. Ellsins.
	2 26	Paragould	36 05	90 30	(?)	1		....do.	Felt by one	
		CALIFORNIA.								
10	11 15	Atascadero	35 20	120 30	4	1		None	Felt by several	Mrs. E. Disney.
	11 20	Lindsay	36 20	119 15	4	1		....do.	....do.	Basil Prior.
		Los Alamos	34 45	120 15	4	1		....do.	Felt by many	H. R. Geve.
		Paso Robles	35 40	120 30	5		30		Felt by everyone	E. J. Nye.
		....do.	35 40	120 30	5	1	15	None	Felt by many	Anna Z. Campbell.
		Salinas	36 41	121 39	3-4	2	Few.	....do.	....do.	Dr. E. D. Eddy.
	11 22	Maricopa	35 05	119 23	5	1	15-18	....do.	....do.	E. F. Foulke.
		San Luis Obispo	35 13	120 45	5	2	30; 2-3	....do.	Union Oil Co. pipe line broken	J. E. Hissong.
	11 23	Angiola	36 00	119 30	3	1		....do.	Felt by several	J. Bulfinch.
		Fresno	36 40	120 00	3	1	30	....do.	Felt by many	C. E. Bonnett.
		Los Angeles	34 03	118 15	5	1	Few.	....do.	....do.	A. W. Pugh.
	11 24	Shando	35 30	120 10	7	1	10-15	Loud	Felt by all; severe	C. U. Margetts.
	11 25	Antelope Valley			7	3	15, 6, 4	Rumbling	Felt by many	Union Oil Co.
		Bakersfield	35 22	119 00	3	1		None	Felt by several	P. W. Doane.
		Cholame	35 35	120 10	8	3	30		Felt by all; some damage	H. I. Jespersen.
		Spreckels	36 38	121 36	4	1	60 *ca.*	None	Felt by many	Spreckels Sugar Co.
		Springville	36 00	119 00		1	30 *ca.*	....do.	Felt by several	Mary E. Birkhead.
	11 40?	Simmler	35 15	120 00	6-7	1	60		Felt by all	F. B. King.
16	23 10	Antelope Valley			4	2	5, 5	Faint	Felt by several	Union Oil Co.
		Paso Robles	35 40	120 30	4		10 *ca.*	None	Felt by many	E. J. Nye.
		....do.	35 40	120 30	5	1	4	....do.	....do.	Anna Z. Campbell.
	23 12	San Luis Obispo	35 13	120 45	5	1	10	....do.	....do.	J. E. Hissong.
	23 15	Atascadero	35 20	120 30	3	1		....do.	Felt by several	Mrs. E. Disney.
	23 20	Shandon	35 30	120 10	4-5					C. U. Margetts.
19	23 00	Paso Robles	35 40	120 30	3	1		None	Felt by several	Mrs. Anna Z. Campbell.
23	10 00	....do.	35 40	120 30	3	1		....do.	....do.	Do.
25	12 00	....do.	35 40	120 30	3	1		....do.	....do.	Do.
		ILLINOIS.								
22	22 23	Waterloo	38 20	90 12	3	2	1		Felt by several	Leonora C. Eilbraith.
		....do.	38 20	90 12	3	2	1	Rumbling	....do.	E. Redbury.
	22 29	Cairo	37 00	89 05	4-5	2-3	30	None	Felt by many	W. E. Barron.
	22 31	Anna	37 30	89 15	5	(?)	20	Rumbling	....do.	Dr. E. V. Hale.
	22 30	New Burnside	37 35	88 50	5	1	15	....do.	....do.	Miss Mae McCabe.
23	2 22	Anna	37 30	89 15	5	1	30	None	....do.	Dr. E. V. Hale.
	2 15	New Burnside	37 35	88 50	5		15	Rumbling	....do.	Miss Mae McCabe.
	2 21	Cairo	37 00	89 05	4-5	1	20	....do.	....do.	J. F. McGruder.
	2 23	Harrisburg	37 45	88 35	4	1	10-12	None	....do.	C. Bonnell.
30	16 52	Cairo	37 00	89 05	2	1	10	....do.	Felt by several	W. E. Barron.
		INDIANA.								
23	2 26	Terre Haute	39 30	87 25	4	2	20-30	None	Felt by several	U. S. Weather Bureau.
		KENTUCKY.								
22	22 20	Clinton	36 45	89 00	5	1	30 *ca.*	Yes	Felt by several	D. Johnson.
		Paducah	37 05	88 40	3	1	7 *ca.*	Faint	Felt by many	J. T. Ross.
	22 21	Columbus	36 45	89 05	5		30	None	....do.	Lavirne Snell.
	22 30	Arlington	36 50	89 00		1	30		Felt by several	L. B. Owen.
		Fulton	36 30	88 50					Very slight	J. R. Graham.
		Hickman	36 34	89 12	3	1	5 *ca.*	None	Felt by many	G. Johnson.
		Marion	37 20	88 05		1	30		....do.	B. C. Paris.
		Mayfield	36 45	88 40	4	1	10		....do.	E. D. Dauthit.
		....do.	36 45	88 40		1	30	Rumbling	....do.	W. L. Hall.
		Wickliffe	37 00	89 05	4	2	2-4	Faint	....do.	J. A. Hines.
	22 35	Blandville	37 00	89 00	3?	1		....do.	....do.	E. W. Horn.
23	21 45	....do.	37 00	89 00	5	1	5-6	Yes	Felt by several	Do.
	22 22	Fulton	36 30	88 50					Very slight	J. R. Graham.
	22 30?	Hopkinsville	36 50	87 30	3?	1			Felt by several	Judge H. Wood.
	22 *ca.*	Murray	36 40	88 15					Slight	Postmaster.
	22 *ca.*	Owensboro	37 50	87 00		1	1	Loud	Weak	Col. J. M. Holmes.
	22 10	Wickliffe	37 00	89 05	4	1	2-4	Faint	Felt by one	J. A. Hines.
	22 15	Louisville	38 15	85 45	1	1	<60	None	....do.	J. L. Eschrich.
	22 20	Arlington	36 50	89 00			20 *ca.*		Felt by several	L. B. Owen.
		Owensboro	37 50	87 00					Very slight	Col. J. M. Holmes.
		Marion	37 20	88 05		1	15		Felt by several	B. C. Paris.
	22 22	Mayfield	36 45	88 40	4	1	15		Felt by many	N. E. Dauthit.
	22 24	Paducah	37 05	88 40	5	1	15 *ca.*	Rumbling	....do.	J. T. Ross.
	22 25	Columbus	36 45	89 05	5		20	None	....do.	J. B. McDearmon.
		Mayfield	36 45	88 40		1	30	Rumbling	....do.	W. L. Hall.
	22 30	Clinton	36 45	89 00	4	1	30		....do.	D. Johnson.
		Hickman	36 34	89 12	4	1	10	None	....do.	G. Johnson.
	22 50	Leitchfield	37 30	86 20	2-3	1	Few.	Faint	Felt by several	P. Pierce.
30	16 30	Hickman	36 34	89 12	3	1	8	Rumbling	....do.	G. Johnson.
	16 53	Arlington	36 50	89 00					Slight	L. B. Owen.
	17 *ca.*	Clinton	36 45	89 00	3?	1	Short.	None	Felt by several	Mrs. D. Johnson.
		Wickliffe	37 00	89 05	2	1	2-4	....do.		J. A. Hines.
	17 30	Mayfield	36 45	88 40	4	1			Felt by many	N. E. Dauthit.

TABLE 1.—*Noninstrumental earthquake reports, March, 1922*—Continued.

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		MICHIGAN.								
1922.	*H. m.*		° ′	° ′			*Sec.*			
Mar. 16	9 30	Port Huron	43 00	82 30	3			Faint	Felt by several	R. C. West.
		MISSOURI.								
22	22 29	Jackson	37 30	89 40	5		30	None	Felt by many	J. G. Putz.
	22 45	New Madrid	36 35	89 32			1	do	Felt by several	Miss J. G. Smith.
	22 30	Poplar Bluff	36 50	90 25	4			Rumbling	Felt by many	J. A. Gallaher.
23	2 20	do	36 50	90 25	4			do	do	Do.
	2 22	Jackson	37 30	89 40	5		30	None	do	J. G. Putz.
	2 35	New Madrid	36 35	89 32				do	do	Miss J. G. Smith.
28	16 42	Poplar Bluff	36 50	90 25	2	3	1	do	Felt by two	J. A. Gallaher.
30	16 45	New Madrid	36 35	89 32	1			Rumbling	Felt by many	Miss J. G. Smith.
		TENNESSEE.								
22	22 30	Memphis	35 10	90 00	3?	1	2–3	None	Felt by two	H. B. Cullen.
		Union City	36 30	89 00	3?	1	13	Rumbling	Felt by many	J. R. Oliver.
	22 30 *ca.*	Brownsville	35 40	89 15	2	2	3 *ca.*	Faint	Felt by several	R. Moses.
	22 30	Troy	36 20	89 07	5	1	30		Felt by many	D. Crockett.
23	2 15	Union City	36 30	89 00	3?	1	10	Rumbling	Felt by several	J. R. Oliver.
	2 25	Troy	36 20	89 07	5	1	30		Felt by many	D. Crockett.
	2 15	Memphis	35 10	90 00	3	1	20	None	Felt by several	Miss C. Metcalf.
30	16 53	do	35 10	90 00	3	1	1	do	Felt by many	J. D. Blagden.
	22 20	Arcadia	36 30	82 30	4	1	Short.	do	Felt by several	Arcadia College.
	2 20	do	36 30	82 30	4	1	Slight.	do	Felt by many	Do.
	2 20	Farmington	35 30	86 45	5	1	Few.	Faint	do	R. Forsyth.

TABLE 2.—*Instrumental seismological reports, March, 1922.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols, see REVIEW for January, 1922.]

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 4		P	13 21 00				7,200	P and S well marked.
		S	13 29 39					
		F	14 05 *ca.*					
10		e	11 34 ..					
		M	11 41 05		*4,500			
		F	12 *ca.*					
10		e	17 18 34					
		F	17 30 *ca.*					
12		eL	17 40 ..					Faint trace.
		F	17 45 ..					
16		e	23 26 40					
		F	23 40 ..					
22		P	22 35 10					
		F	22 37 ..					Faint.
28		P	4 09 56				6,500	
		S	4 17 59					
		L?	4 28 ..					
		L	4 37 45	18				
		F	4 45 *ca.*					

* Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 4		P	13 19 22				6,400	NS off sheet.
		PR1	13 22 02					
		S	13 27 20					
		L	13 37 10					
		F	15 *ca.*					Lost in micros.
10		P	11 31 58				1,900	
		S	11 35 15					
		M_N	11 38 *ca.*			*10,000		
		F	12 40 *ca.*					Lost in micros.
10		P	17 16 51					
		S?	17 20 38					
		F	17 50 ..					Lost in micros.

* Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 12		P?	17 03 10					
		S?	17 14 07					
		eL	17 25 ..	24				
		L	17 42 ..	15				
		F	18 45 *ca.*					
16		e	23 24 40					
		F	23 35 *ca.*					
22		P	22 31 18				400	Felt in Mississippi Valley.
		S	22 31 58					
		L?	22 33 25					
		F	22 45 *ca.*					
23		P	2 23 10				400	
		S	2 23 50					
		F	2 28 ..					
28		P	4 08 24					
		S?	4 28 10					
		L	4 40 ..	15				
		F	6 *ca.*					

MISSOURI. *St. Louis University, St. Louis.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 4		iP	13 18 35				7,700	
		iS	13 27 40	5	*3,000			
		eL	13 38 ..	3	*1,000			
		F	15 06 ..					
10		eL	10 52 ..					Merges into next quake.
10		eP	11 27 ..				3,900	
		S	11 34 30					
		eL	11 36 ..					
		M	11 36 35	6		*4,000		
		F	11 51 ..					
22		iP	22 29 39					Oscillations very rapid. Felt in Missouri, and adjacent States to S., SE., and E.
		iS	22 30 ..					
		M	22 30 06		*2,000			
		F	22 34 ..					
22		i	22 39 39			*1,000		
23		i	2 22 ..					Felt in St. Louis and Illinois.

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, March, 1922*—Continued.

NEW YORK. *Cornell University, Ithaca.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 10		L	11 39 ..	28				
		L	11 40 07	18				
		L	11 42 36	12				
		F	12 11 ..					
12		L	17 37 ..	23				
		F	17 43 ..					
22		eP	22 34 57	2				
		S	22 35 26	5				
		F	22 36 30					
28		iP$_N$	4 08 19	5				
		iS	4 16 45	6				
		eL	4 35 ..	20				
		L	4 59 30	7				
		F	5 07 ..					

NEW YORK. *Fordham University, New York.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 4		eP$_N$	13 20 01				7,100	
		eP$_E$	13 20 01					
		eS$_N$	13 28 37					
		eS$_E$	13 28 35					
		eL$_E$	13 38 47					
10		eP?$_E$	11 37 54					Obscured by micros.
		eP?$_N$	11 37 56					
		eS?$_N$	11 40 58					
		eL?$_E$	11 43 05					
28		eP$_N$	4 08 09				6,800	
		eP$_E$	4 08 09					
		eS	4 16 23					
		eL$_E$	4 23 18					

CANAL ZONE. *Panama Canal, Balboa Heights.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 28		P	4 04 18				3,700	Probably northerly.
		S$_E$	4 09 16					
		S$_N$	4 09 32					
		M$_E$	4 09 24		*500			
		M$_N$	4 09 36			*600		
		F$_E$	4 28 00					
		F$_N$	4 40 30					

* Trace amplitude.

VERMONT. *U. S. Weather Bureau, Northfield.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 4		P	13 19 49					Feeble.
		S	13 28 06					
		F	14 *ca.*					
10		eL	11 41 00	16				
		L	11 44 ..	12				
		F	12 *ca.*					
28		P	4 08 25				7,200	
		S	4 17 03					
		F	4 25 *ca.*					

CANADA. *Dominion Observatory, Ottawa.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 4		*O*	13 09 30				6,580	Irregular L waves small amplitude and uncertain period.
		iP	13 19 34					
		iPR1$_N$	13 22 07					
		iS	13 27 41					
		eL	13 37 ..					
		F	14 24 ..					
10		eL	11 38 ..					Press report quake in California; no waves P or S recorded here or in Halifax.
		M	11 40 18	17	50	50		
		F	12 25 ..					
		HALIFAX RECORD.						
		e?	12 01 ..					
		eL	12 11 30					
		F	12 16 30					
10		e	17 20 08					Wireless report from Strasburg confirms this as seismic; very small.
		e$_E$	17 23 30					
		F	17 40 *ca.*					

CANADA. *Dominion Observatory, Ottawa*—Continued.

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 12		iS?$_E$	17 14 45					
		eSRL?$_E$	17 20 ..					
		eL$_E$	17 28 ..					
		L$_E$	17 30 ..	30				
		L$_E$	17 56 ..	15				
		F	18 25 ..					
22		e	22 35 44					Small quake in Missouri at this hour; recorded all three comp.; very rapid, small amplitude.
		F	22 36 28					
28		*O*	3 57 53				7,280	Epicentre from Ottawa and Oxford, in South America.
		iP	4 08 36					
		iS	4 17 19					
		eL	4 30 ..					
		L$_E$	4 39 ..	19				
		F	5 35 ..					

CANADA. *Dominion Meteorological Service, Toronto.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 4		e	13 17 42					Micros going on.
		e	13 21 24					
		S	13 24 36					
		iL	13 34 24					
		eL	13 41 06					
		eL	13 52 00					
		M	13 52 42		*800			
		F						
10		P?	11 31 06?					Small micros render P doubtful; California.
		iL	11 40 18					
		M	11 41 00		*800			
		F						Micros.
12		e	17 11 12					Light turned down at 17*h.* 41*m.* to attend to instrument.
		i	17 15 48					
		eL	17 24 48					
		eL	17 27 48					
		M			*300?			
		F	17 34 00					
16		L	23 20 42					Micros.
		F			*100			
26		eL	14 40 48					Distant.
		M	14 44 30		*400			Gradual thickening.
		F						Micros.
28		e?	4 03 36					Marked movements before 4:08:36 may be micros.
		P	4 08 24				7,600?	
		iS	4 17 24					
		M	4 20 12		*500			
		L	4 39 24					
		F	5 32 24					

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 4		e	13 17 09					
		i	13 23 36					
		L	13 28 42					
		M	13 30 02		*600			
		L	13 34 30					
		F	14 28 33					
10		P	11 27 36					Probably California.
		L	11 27 42					
		M	11 29 12		*3,000			
		F	12 16 30					
10		L	17 06 39					
		M	17 19 26		*300			
		F	17 46 29					
12		P	17 16 15					
		L	17 29 02					
		M	17 45 45		*300			
		F	19 45 45					
16		L	23 17 09					
		M	23 18 37		*200			
		F	23 24 31					
26		L	14 19 56					
		M	14 22 55		*200			
		F	14 30 51					
28		P	4 09 16					
		iS	4 19 40					
		M	4 21 09		*500			
		F	4 34 03					
28		L	4 42 59					
		M	4 46 57		*500			
		F	5 20 10					

* Trace amplitude.

No earthquakes were recorded at the following stations during March, 1922:

CALIFORNIA. *Theosophical University*, Point Loma.

COLORADO. *Regis College*, Denver.

Reports for March, 1922, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

ALASKA. *U. S. C. & G. S. Magnetic Observatory*, Sitka.

ARIZONA. *U. S. C. & G. S., Magnetic Observatory*, Tucson.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

HAWAII. *U. S. C. & G. S. Magnetic Observatory*, Honolulu.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham.

MASSACHUSETTS. *Harvard University*, Cambridge.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

O

Chart I. Hydrographs of Several Principal Rivers, March, 1922.

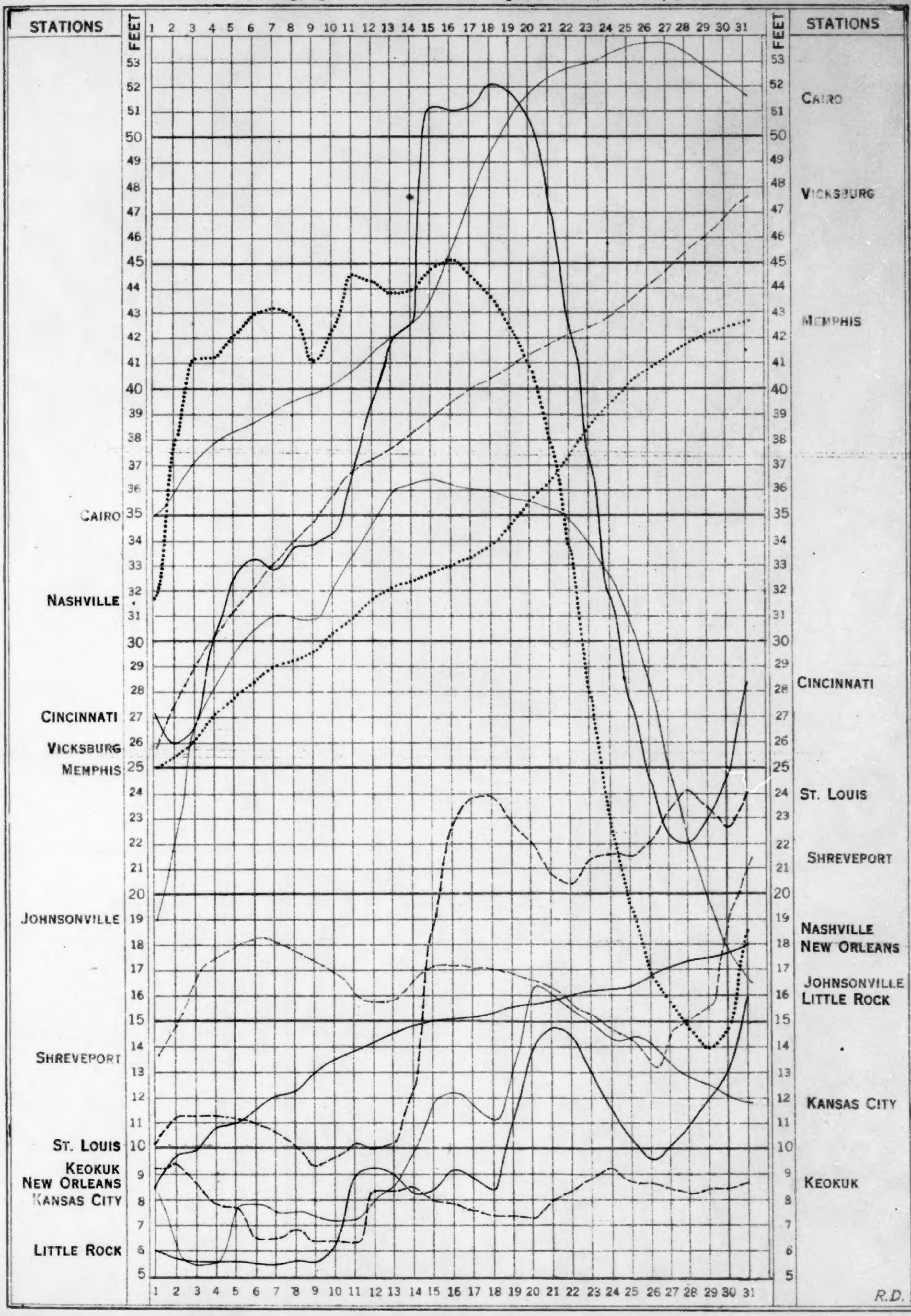


Chart II. Tracks of Centers of Anticyclones, March, 1922. (Inset) Departure of Monthly Mean Pressure from Normal.

(Plotted by Wilfred P. Day.)

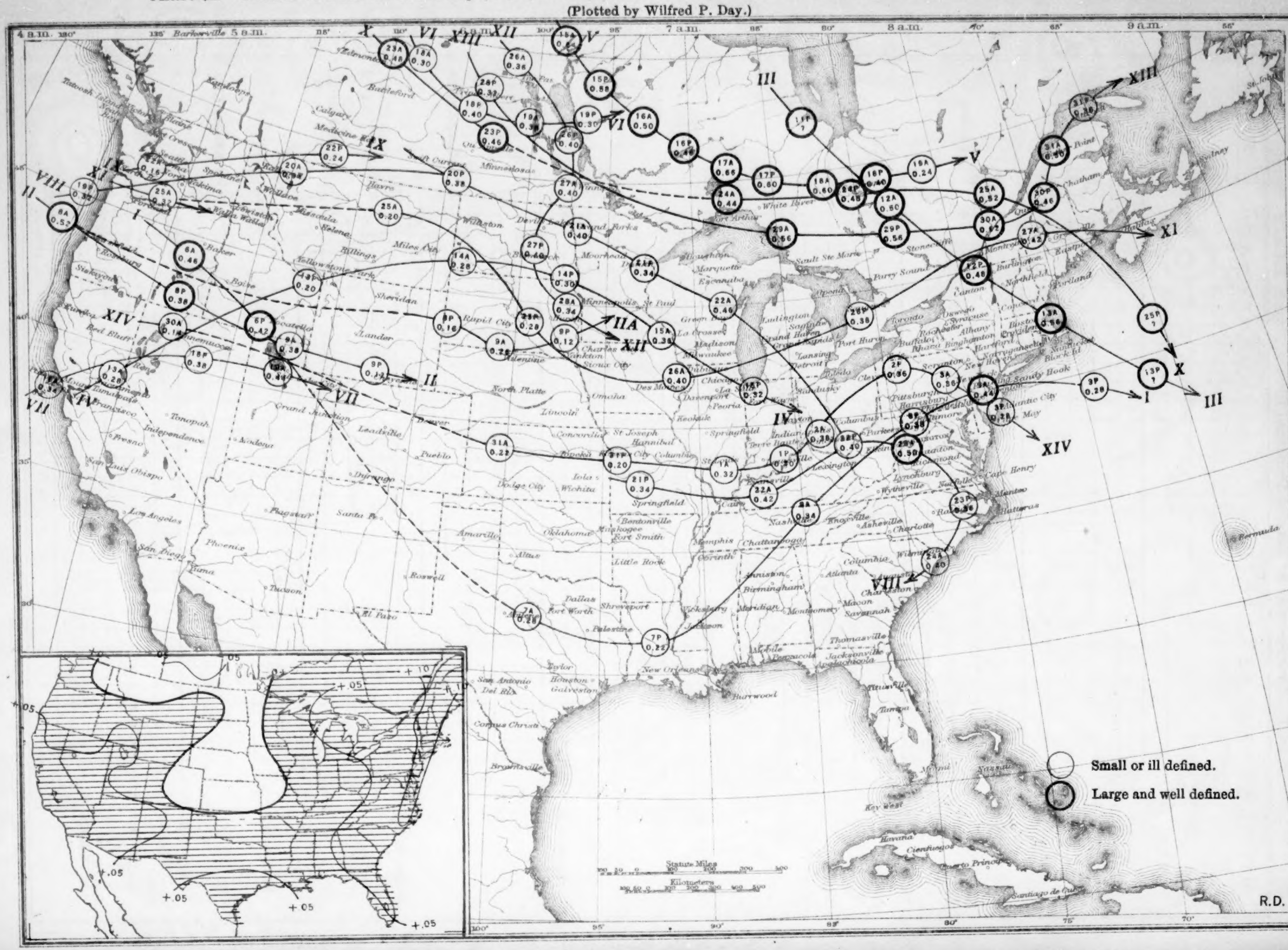


Chart III. Tracks of Centers of Cyclones, March, 1922. (Inset) Change in Mean Pressure from Preceding Month.

Chart III. Tracks of Centers of Cyclones, March, 1922. (Inset) Change in Mean Pressure from Preceding Month.
(Plotted by Wilfred P. Day.)

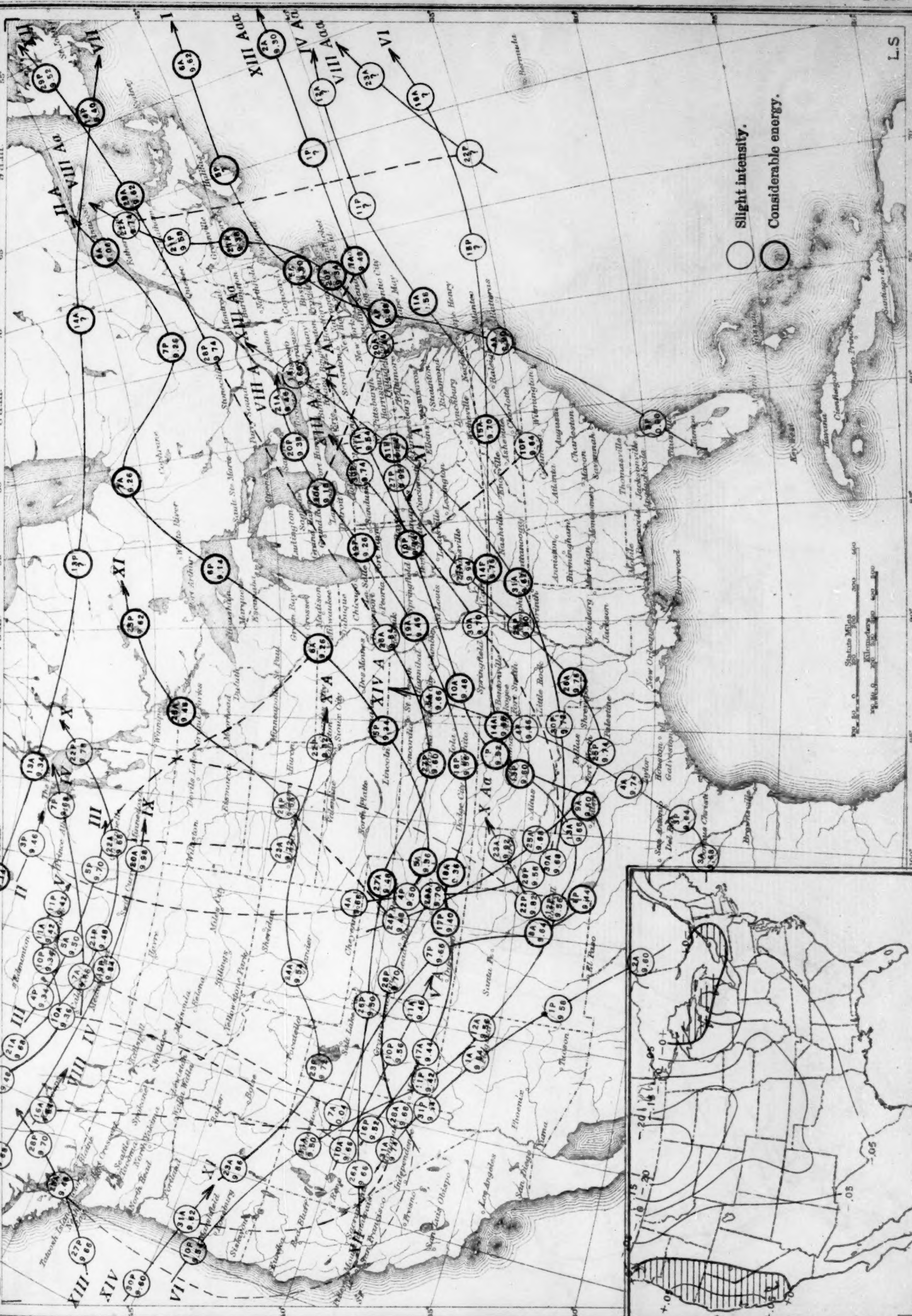


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, March, 1922.

Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart V. Total Precipitation, Inches, March, 1922. (Inset) Departure of Precipitation from Normal.

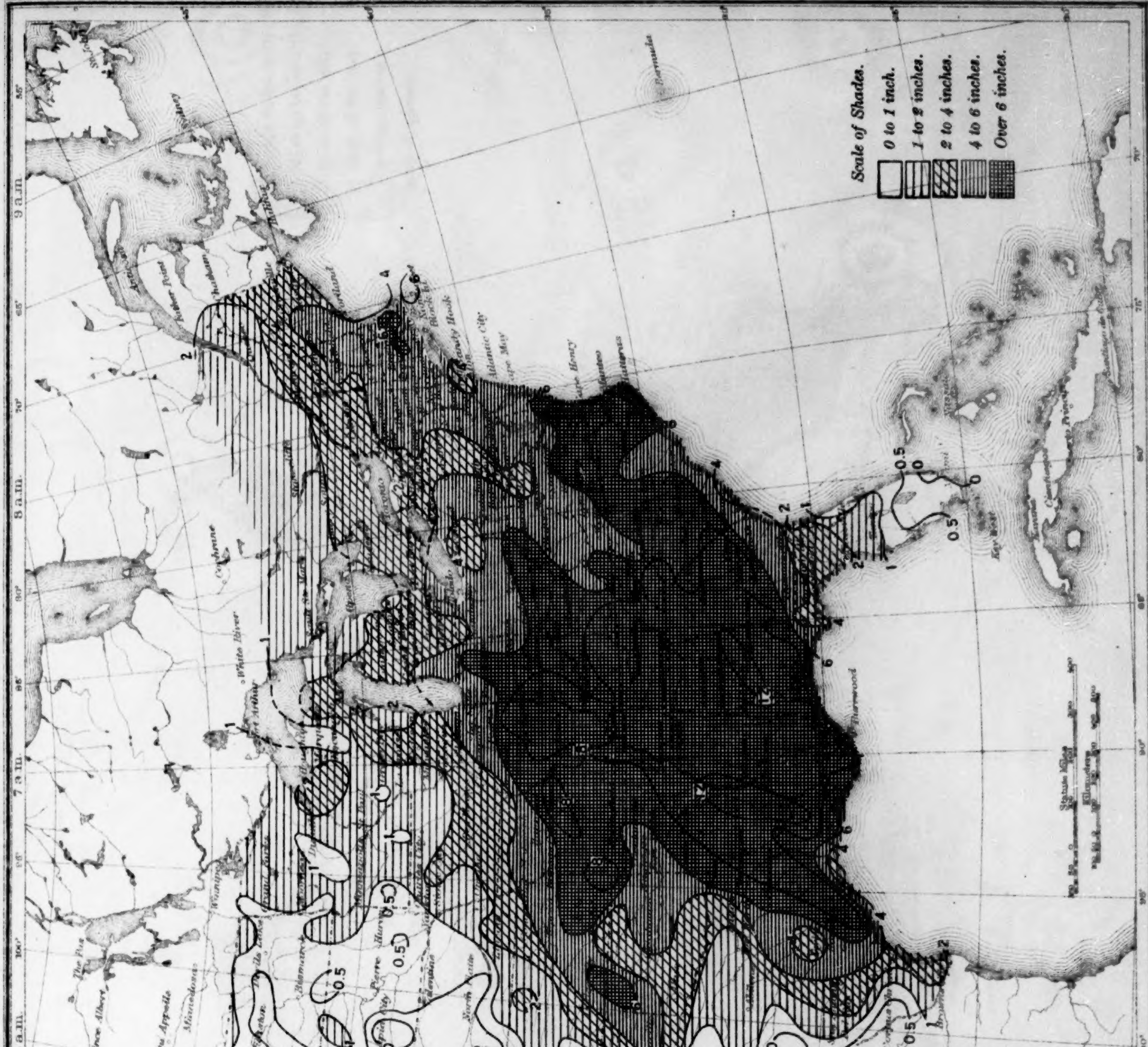


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, March, 1922.

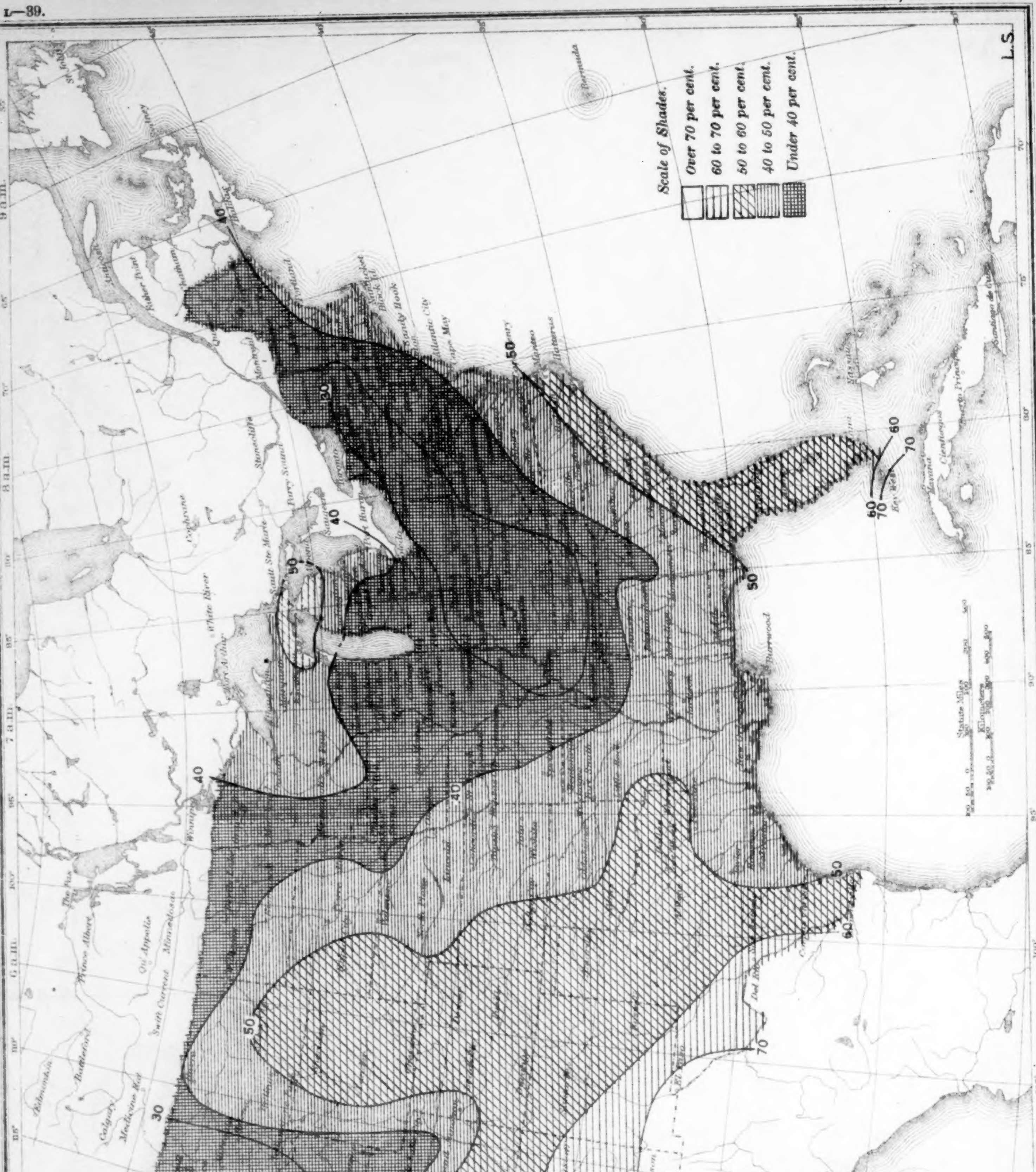


Chart VII. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, March, 1922.

Chart VIII. Total Snowfall, Inches, March, 1922. (Inset) Depth of Snow on Ground at end of Month.

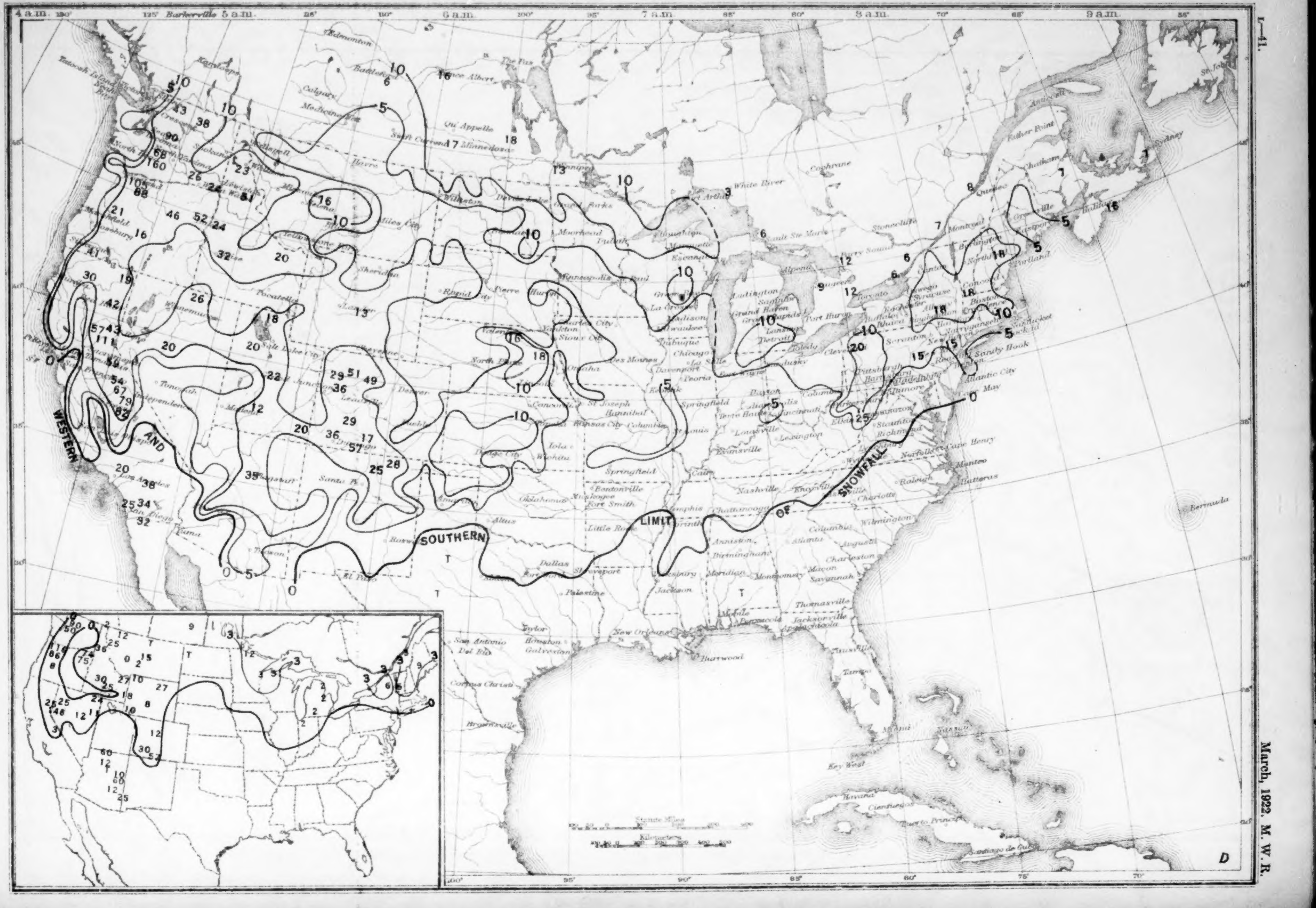


Chart IX. Weather Map of North Atlantic Ocean, March 1, 1922.

Chart IX. Weather Map of North Atlantic Ocean, March 1, 1922.
(Plotted by F. A. Young.)

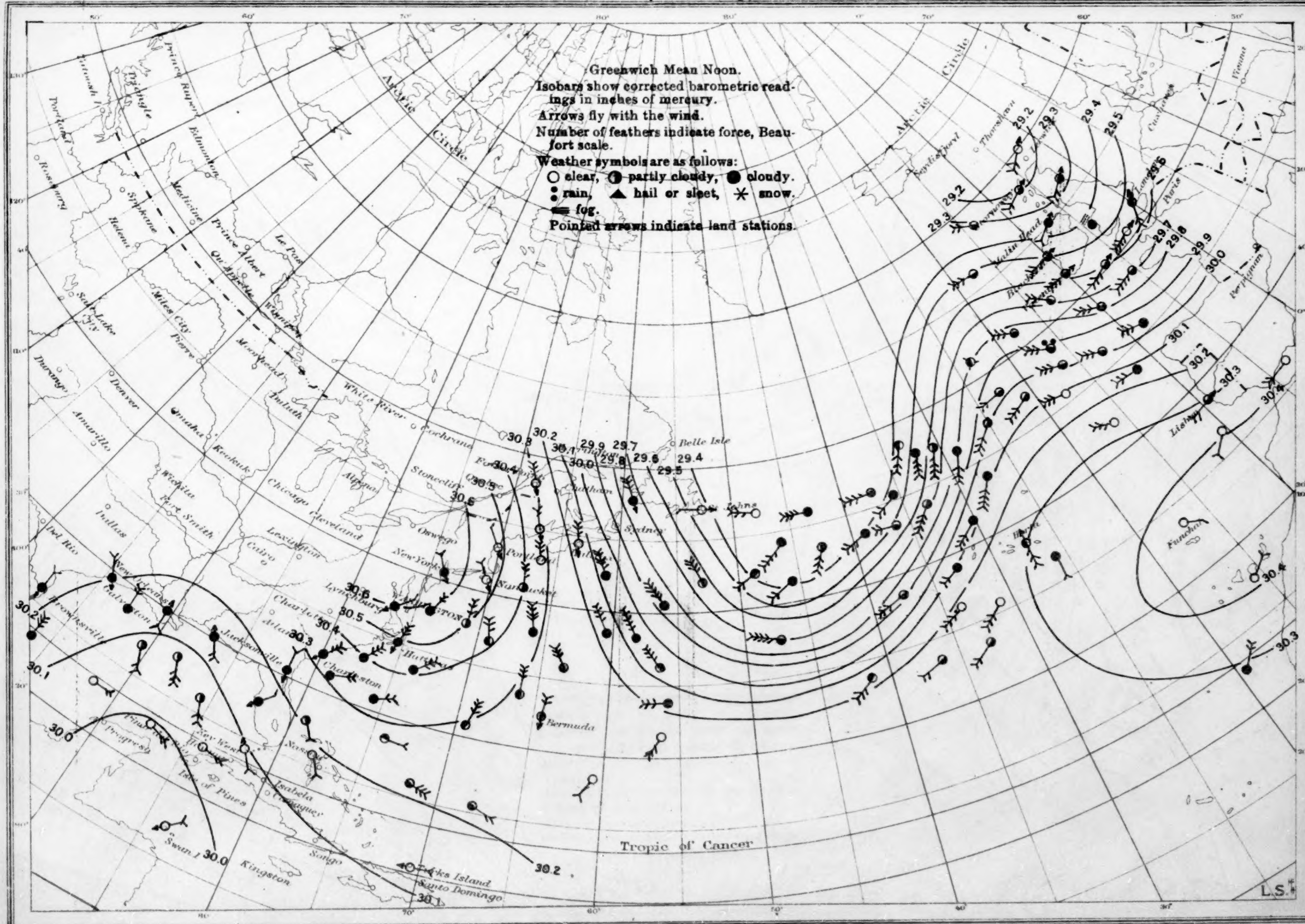


Chart X. Weather Map of North Atlantic Ocean, March 2, 1922.

(Plotted by F. A. Young.)

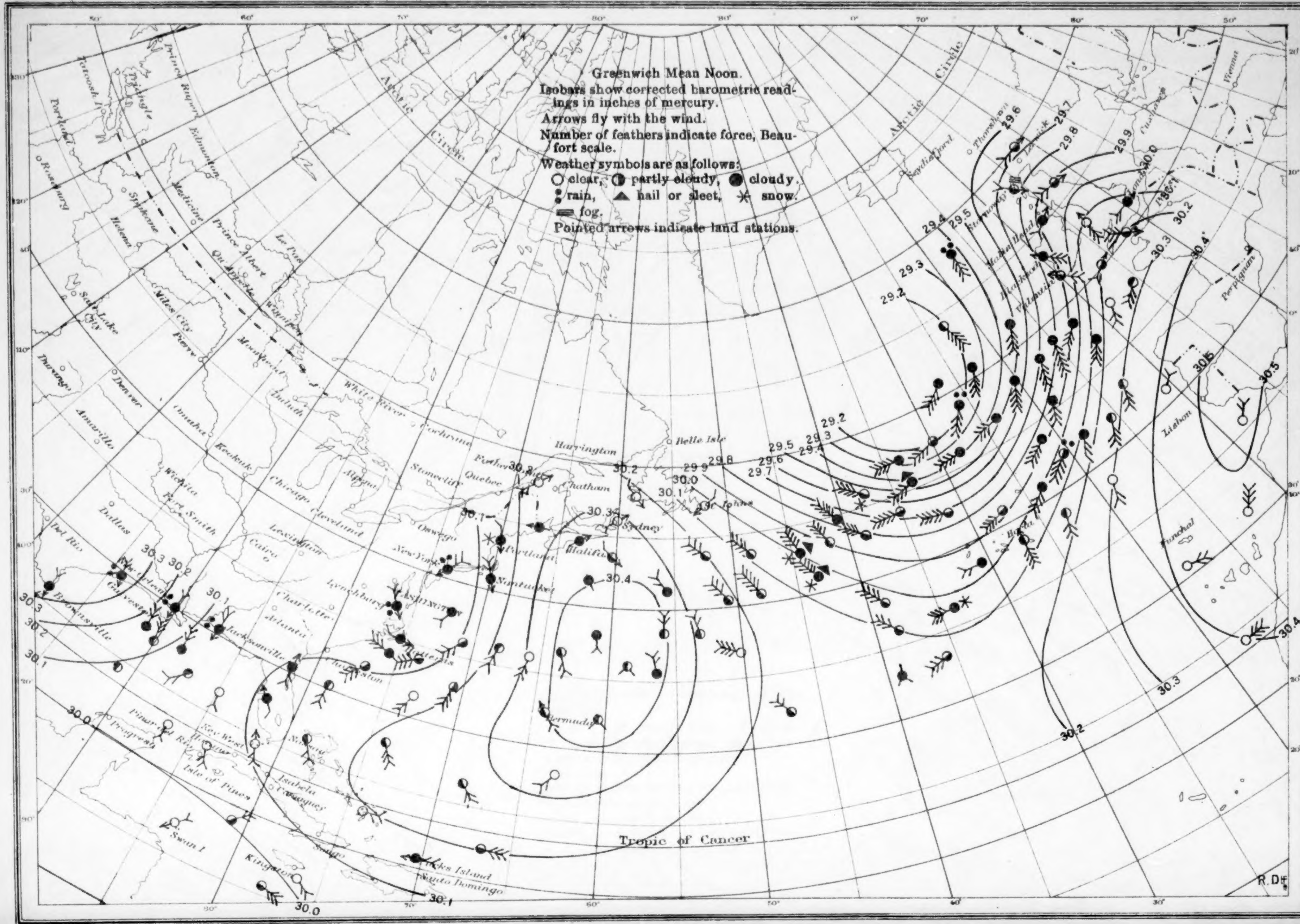


Chart XI. Weather Map of North Atlantic Ocean, March 3, 1922.
(Plotted by F. A. Young.)

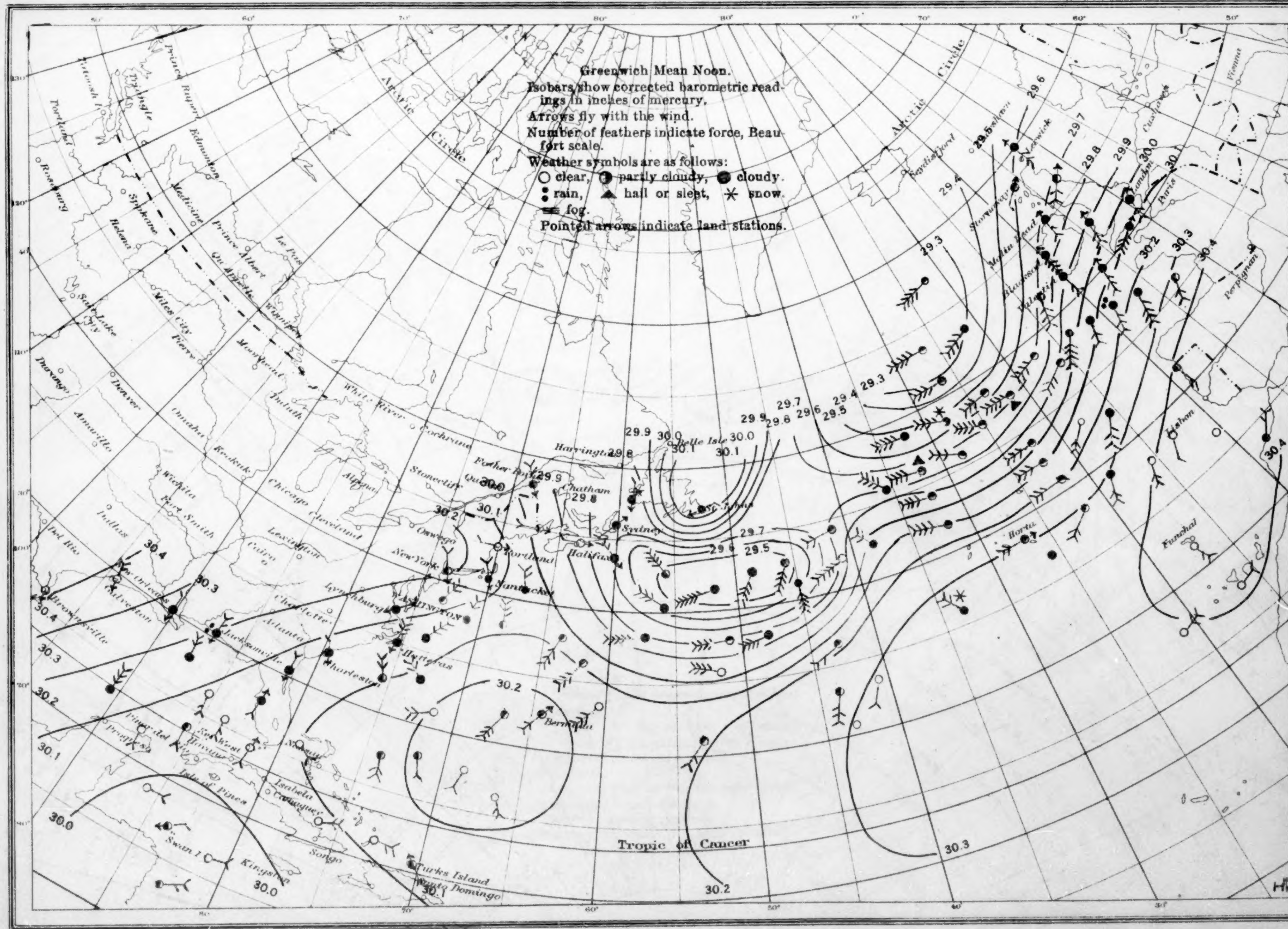


Chart XII. Weather Map of North Atlantic Ocean, March 4, 1922.

(Plotted by F. A. Young.)

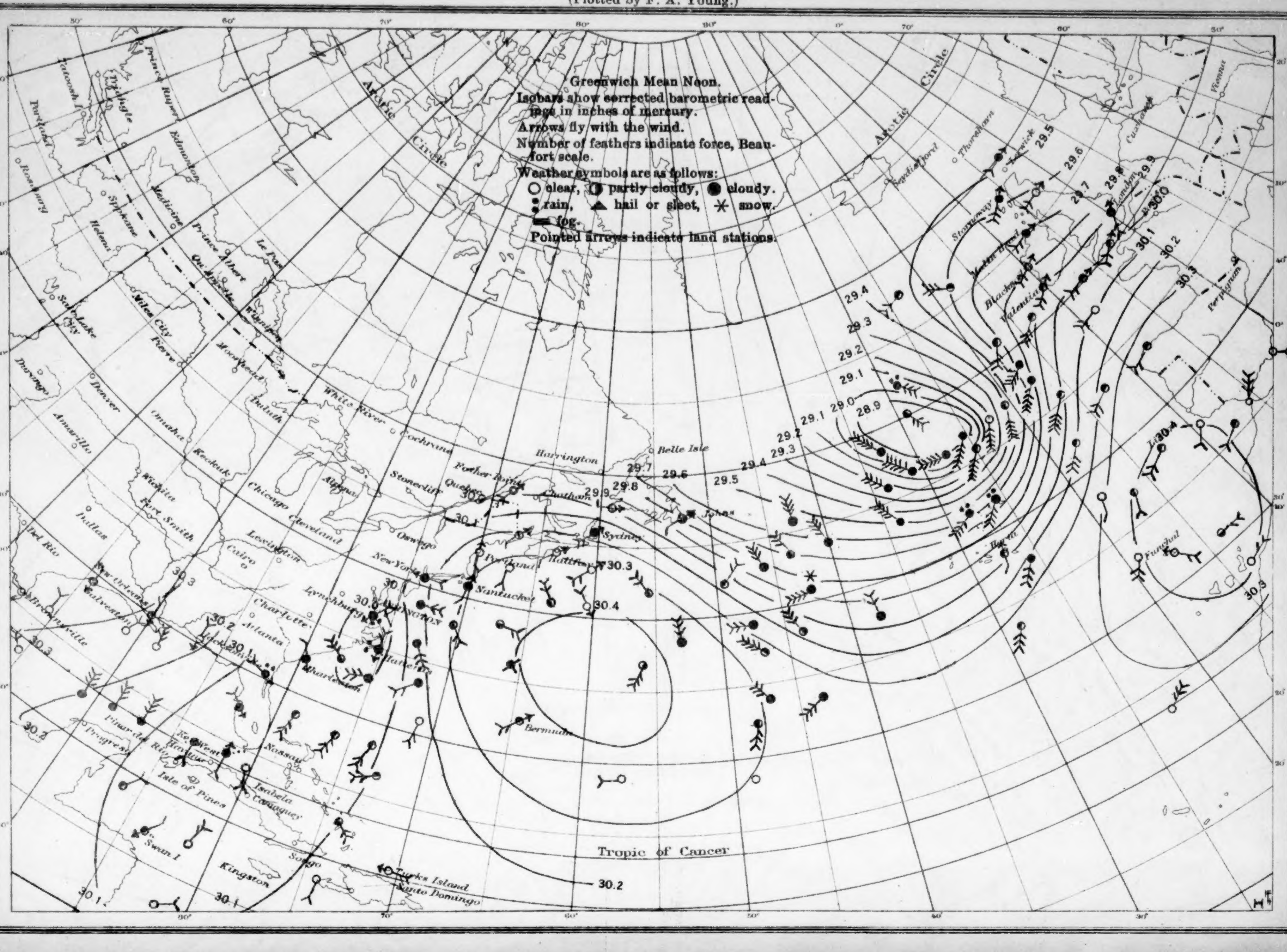


Chart XIII. Weather Map of North Atlantic Ocean, March 5, 1922.

Chart XIII. Weather Map of North Atlantic Ocean, March 5, 1922.
(Plotted by F. A. Young.)

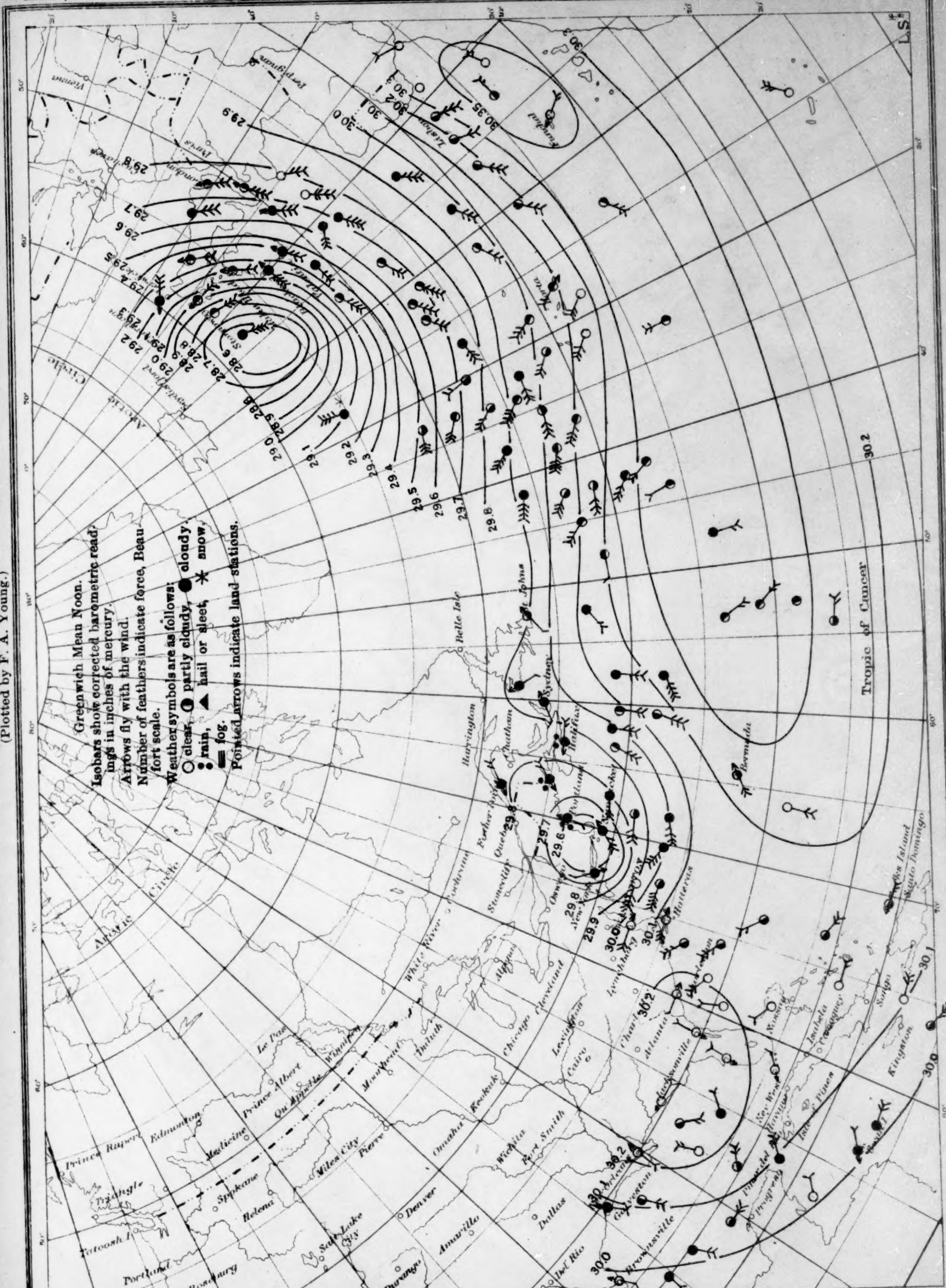
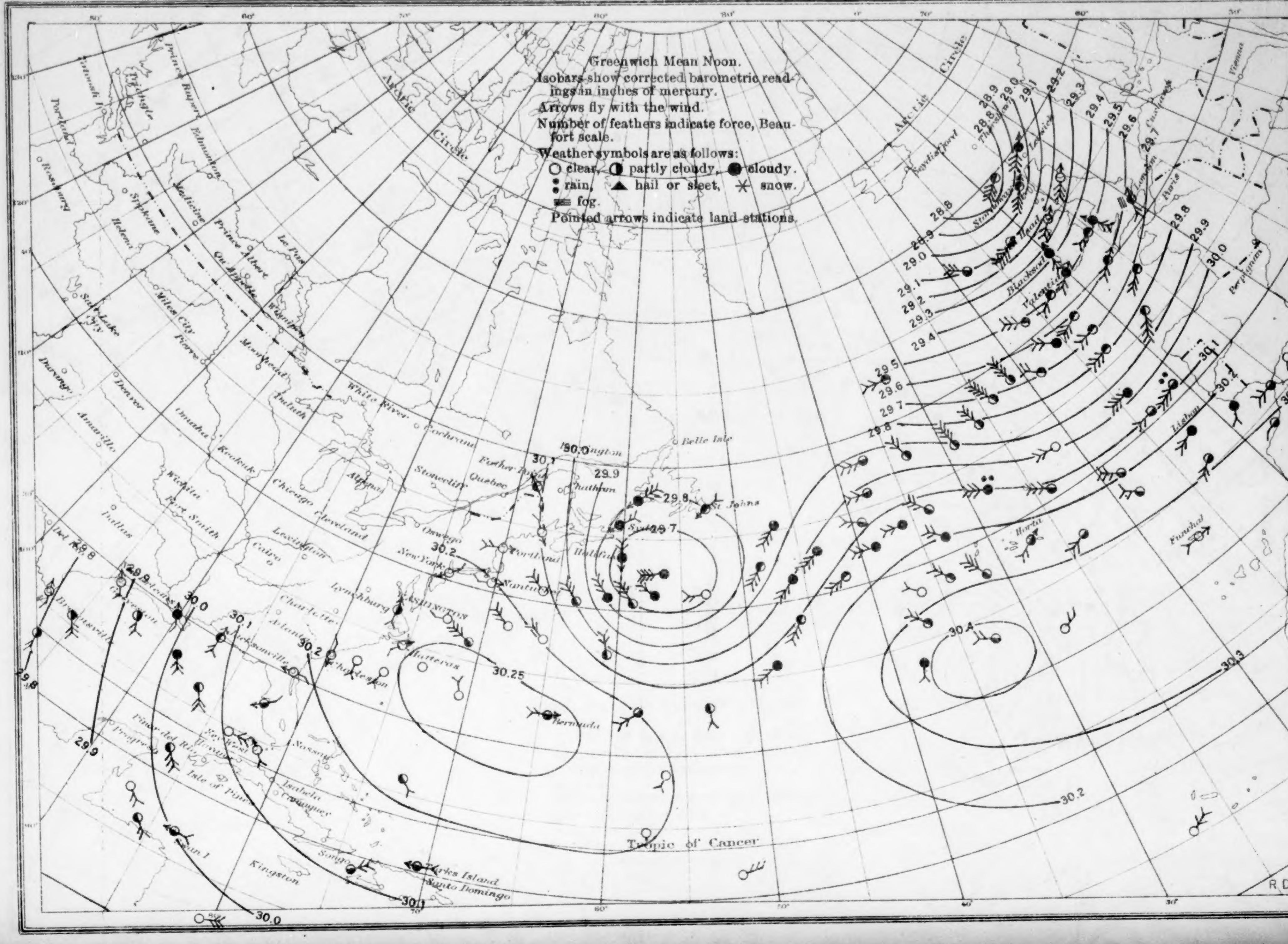


Chart XIV. Weather Map of North Atlantic Ocean, March 6, 1922.

(Plotted by F. A. Young.)



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MARCH, 1922.

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† In marine separate.